UNDERSTANDING POLYESTER RESIN PROCESSING:

THE EFFECT OF AMBIENT TEMPERATURE ON THE FINAL PART

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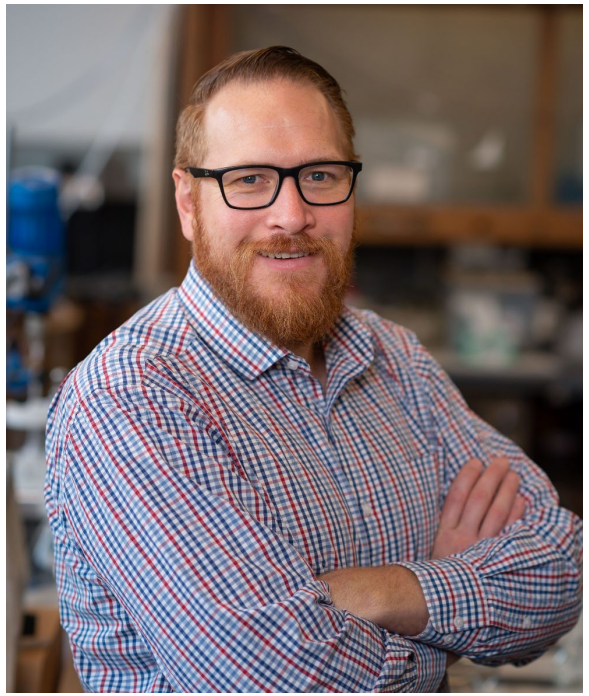
YOUR HOST



Casey Keulen, Ph.D, P.Eng.
Assistant Professor of Teaching, University of British Columbia
Co-Director of Advanced Materials Manufacturing MEL Program, UBC
Co-Director of Knowledge in Practice Centre, CKN

- Ph.D. and M.A.Sc. in Composite Materials Engineering
- Over 15 years experience in industry and academia working on polymer matrix composites in aerospace, automotive, marine, energy, recreation and others
- Experience working with over 150 companies from SME to major international corporations
- Expertise in liquid composite moulding and thermal management

PAST WEBINAR RECORDINGS AVAILABLE

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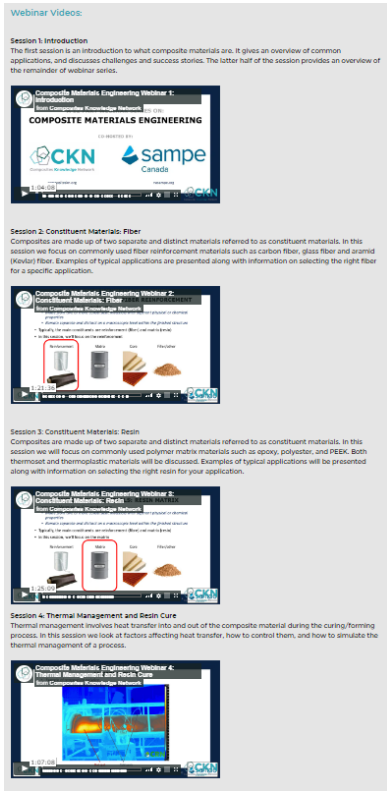

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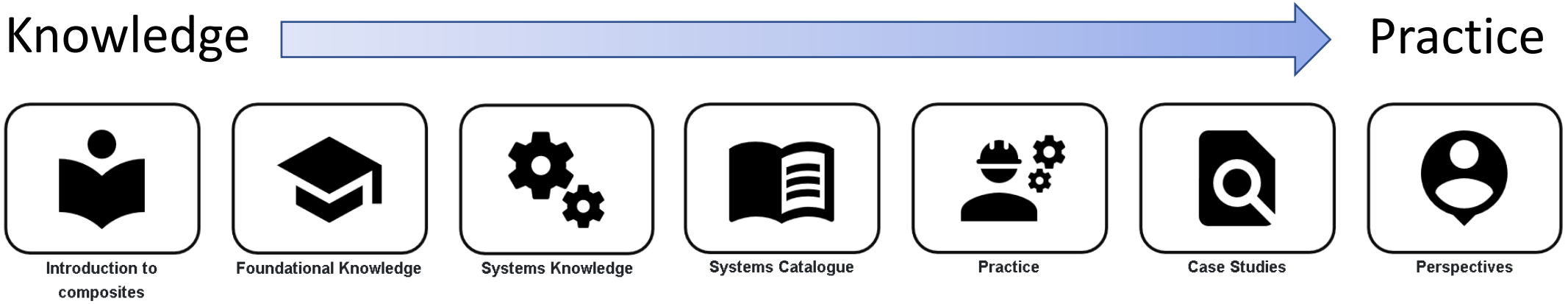
KNOWLEDGE IN PRACTICE CENTRE (KPC)

- A freely available online resource for composite materials engineering:

compositeskn.org/KPC

- Focus on practice, guided by foundational knowledge and a systems-based approach to thinking about composites manufacturing



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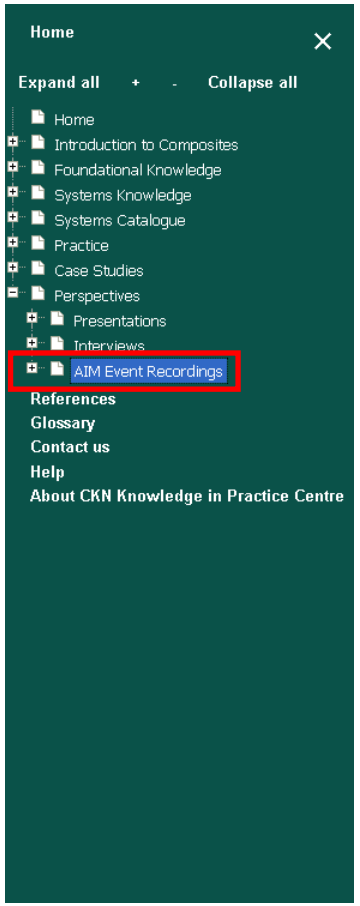

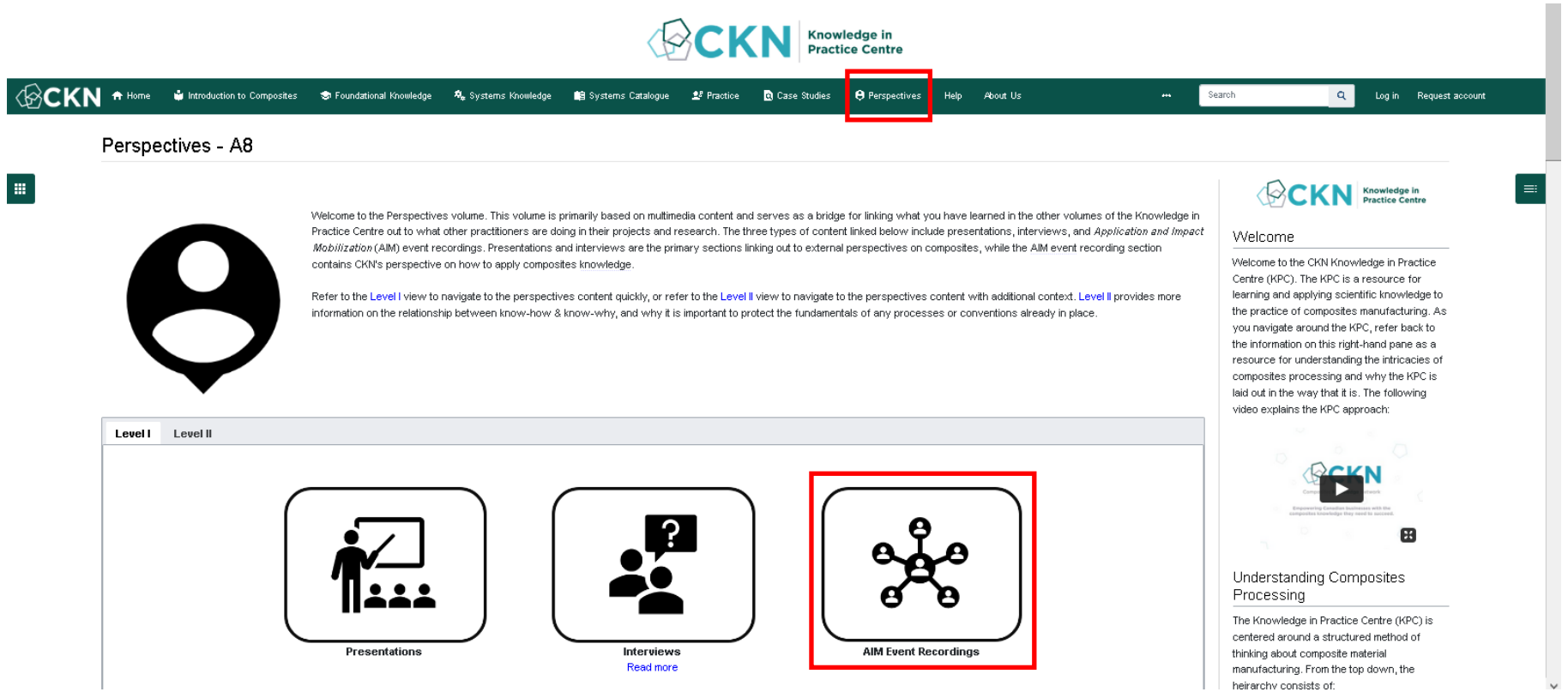

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AIM Event Webinar Recordings:
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TODAY'S TOPIC:

Understanding Polyester Resin Processing:
The effect of ambient temperature on the final part

OUTLINE AND LEARNING OBJECTIVES

Outline

- Introduction to polyester resin
- Curing polyester
  - Degree of cure
  - Heat of reaction
  - Tg
  - Gel time
- Polyester in the context of MSTEP
- Experimental study
- Industrial case study
- Managing the cure

Learning Objectives

- Understand how polyester resins cure
- Understand the parameters that effect cure
- Understand the effect of ambient temperature on the cure of polyester resin
- Understand what can be done to control the cure

INTRODUCTION

- Where does polyester resin fit on the composites landscape?
  - ***Most commonly used matrix for thermoset composites***
  - Advantages
    - Economical
    - Flexible cure process
    - Fast cure time
  - Disadvantages
    - Lower material properties than alternatives (epoxy)
    - Low Tg
    - Health and safety issues
    - Higher cure shrinkage

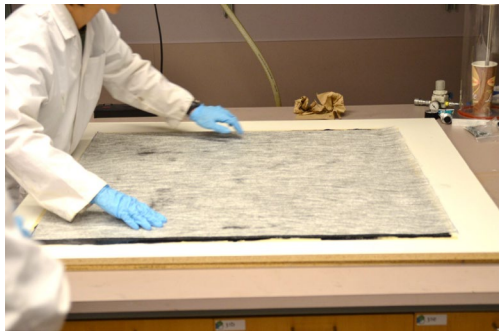
Polyester resin
(One part plus initiator)

INTRODUCTION

- Where does polyester resin fit on the composites landscape?
  - Typically used with glass fibre, rarely with carbon fiber
  - Common applications:
    - Boats/marine
    - Turbine blades
    - Electrical equipment
    - Industrial applications
    - Water slides
    - Truck canopies
    - Pipes/plumbing

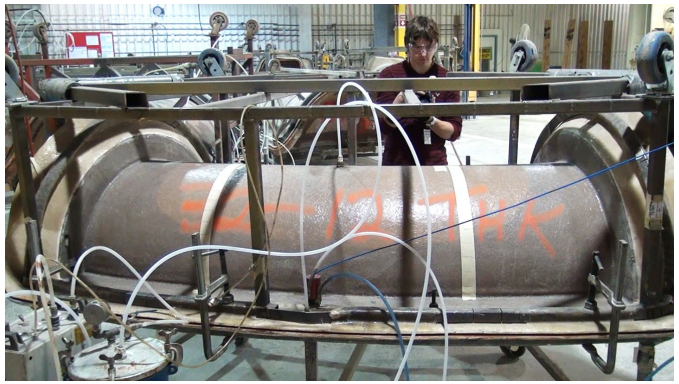
INTRODUCTION

- Common manufacturing processes
  - Hand (wet) layup
  - Spray up
  - Infusion
  - LRTM
  - Pultrusion



Wet/hand layup

Infusion



LRTM

Spray up

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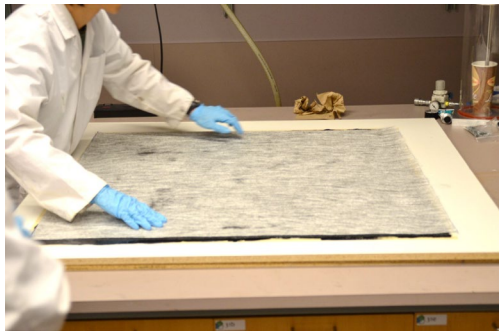
  - ~~Pultrusion~~



Wet/hand layup

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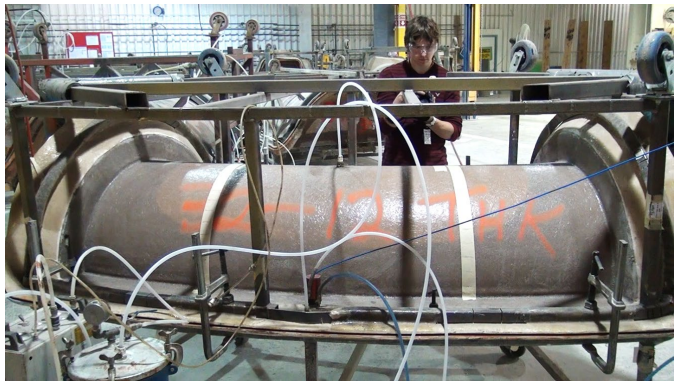
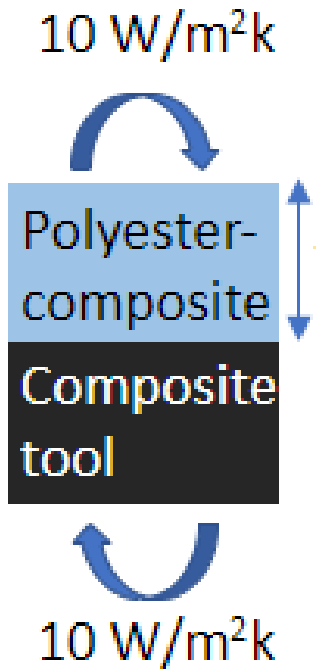


LRTM

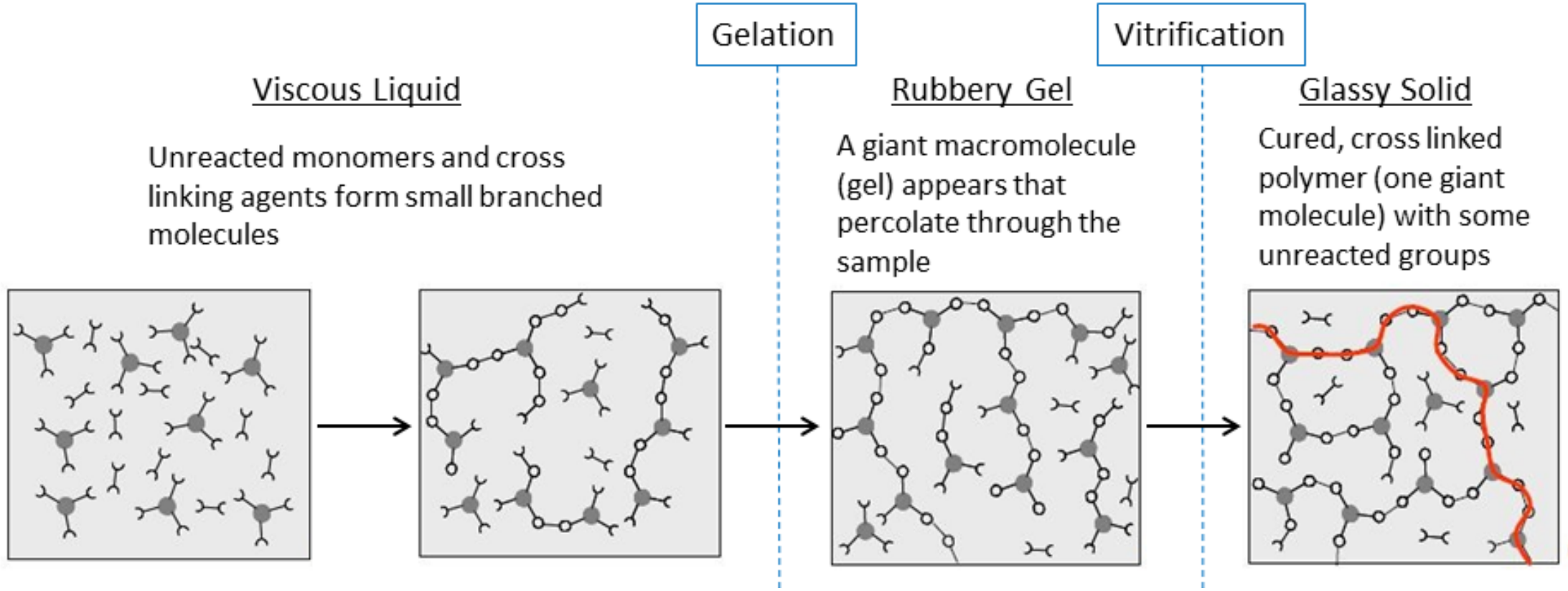
Spray up

INTRODUCTION

- What is typically common to these processes?
  - Ambient curing (ie. cured by leaving at ambient temperatures rather than using active curing)
  - Minimal/no thermal management
- What does this mean for the manufacturer?
  - Less control over outcomes such as:
    - Degree of cure (DOC)
    - Tg
    - Mechanical properties



POLYESTER RESIN CURING



POLYESTER RESIN CURING

- Polyester is a thermoset resin
  - Goes through an irreversible *exothermic* chemical reaction – 'the cure' or 'curing'
- The cure begins when an initiator is added to the resin
- The rate of cure is a function of temperature
- The higher the temperature, the faster the reaction will generate heat, which increases the temperature further
- The faster the reaction, the less working/gel time

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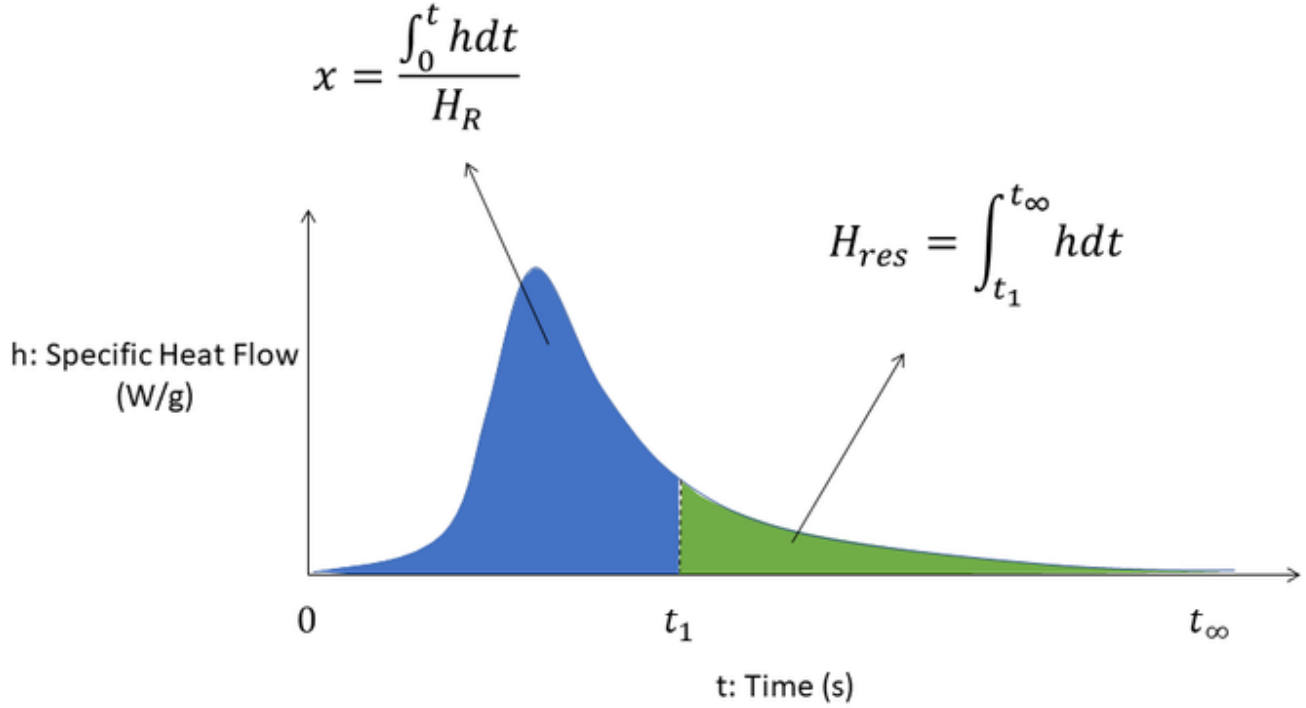
Important to remember that even though the ambient temperature is ~20°C, the temperature that the material experiences is likely much different

POLYESTER RESIN CURING

- What properties and outcomes of the cure are we interested in?
  - *Degree of cure, (DOC)*
- Heat of reaction is used to measure DOC

$$x = 1 - \frac{H_{res}}{H_R}$$

Where: *x = DOC (0-1)*
H_{res} = residual heat of reaction
H_R = total heat of reaction



POLYESTER RESIN CURING

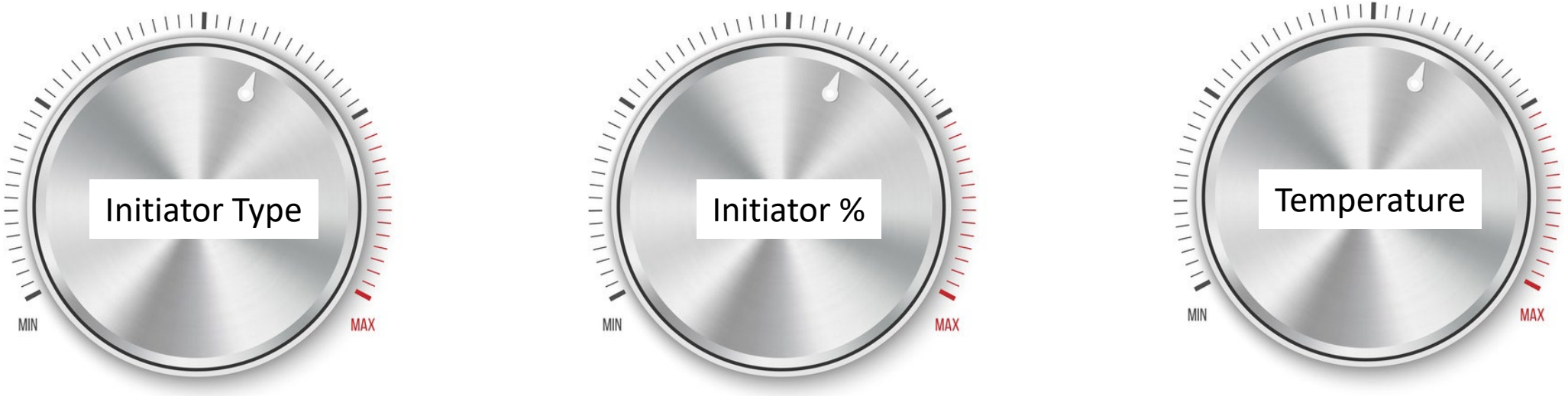
- DOC effects the performance of a composite

- Strength typically increases as DOC increases
- Resistance to chemicals and moisture ingress increases as DOC increases

- Glass transition temperature, Tg indicates when a polymer changes from glassy to rubbery
- Tg increases as DOC increases
  - -> Which relates to it's max operating temperature

POLYESTER RESIN CURING

- Typical curing control knobs:



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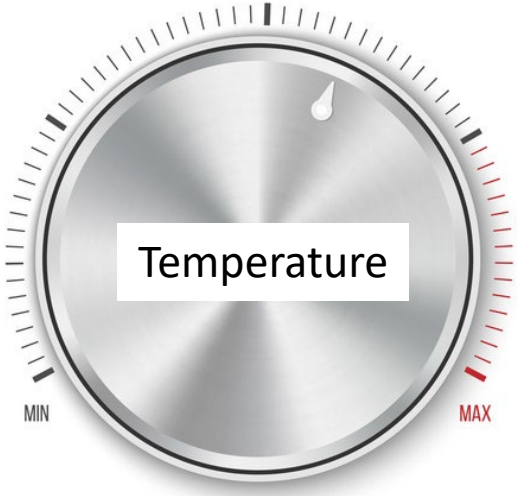

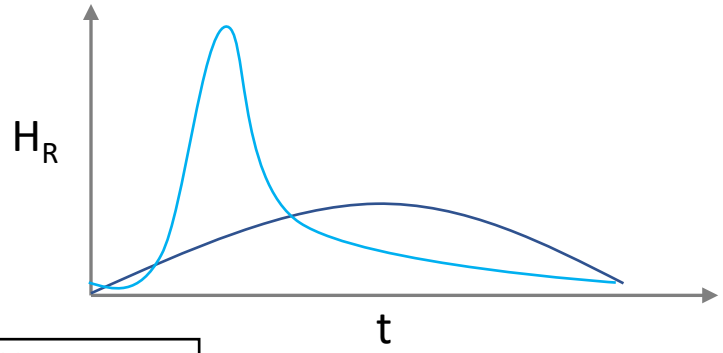

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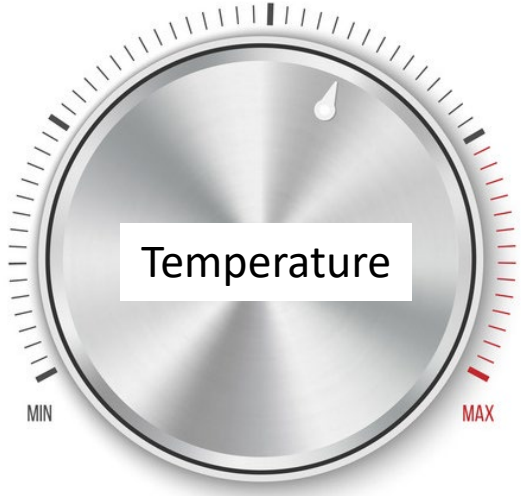
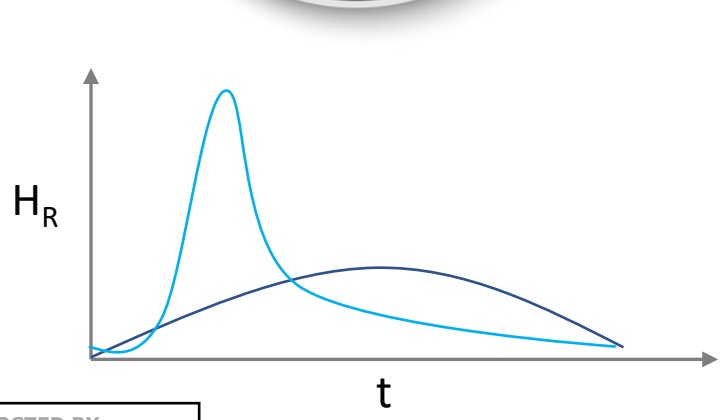
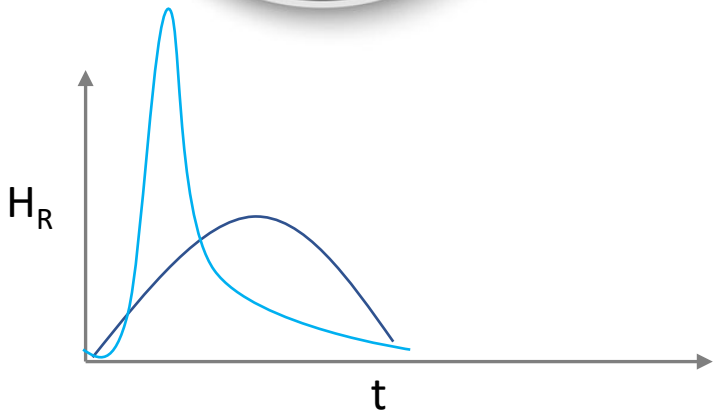
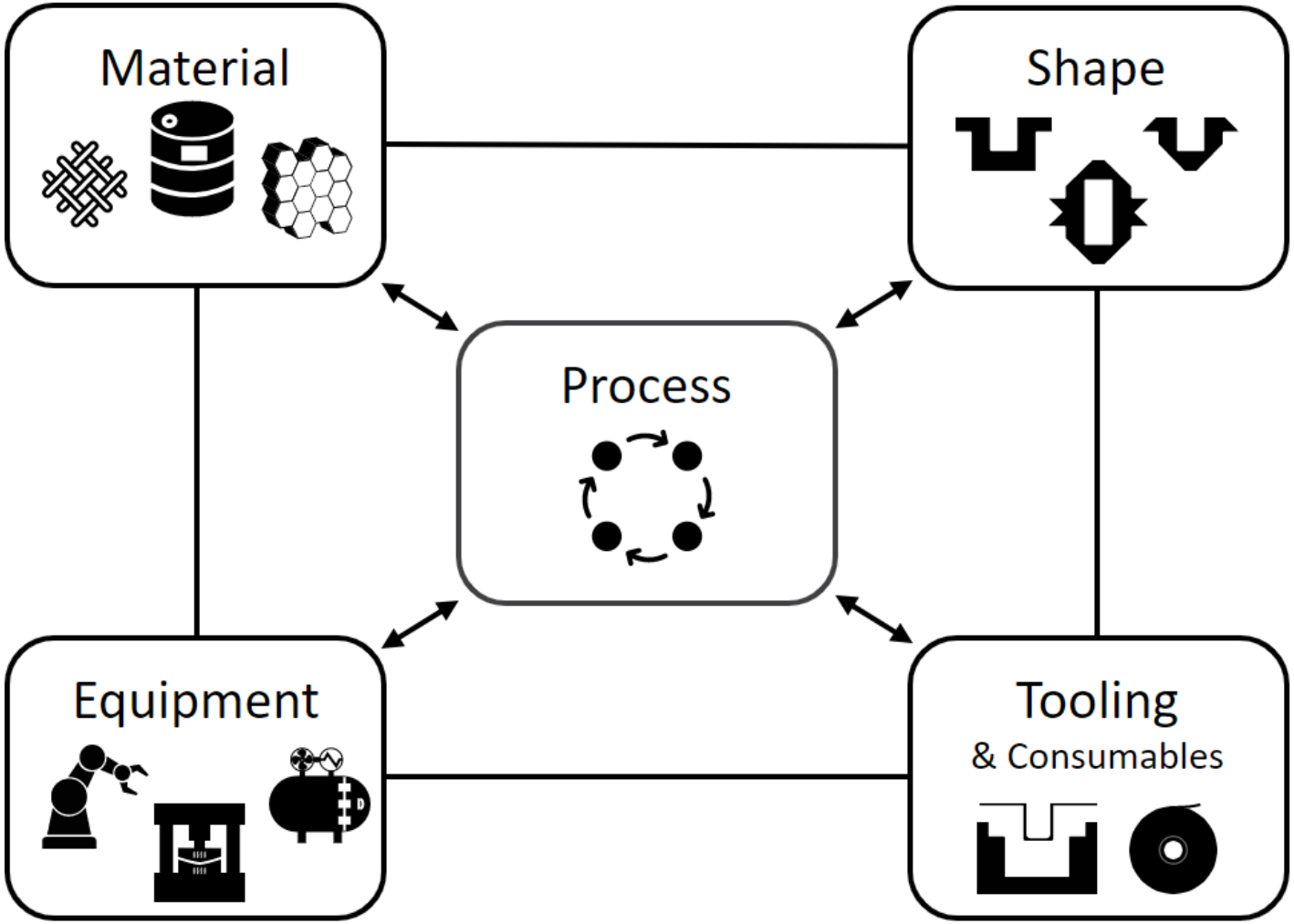






POLYESTER RESIN CURE IN CONTEXT OF MSTEP



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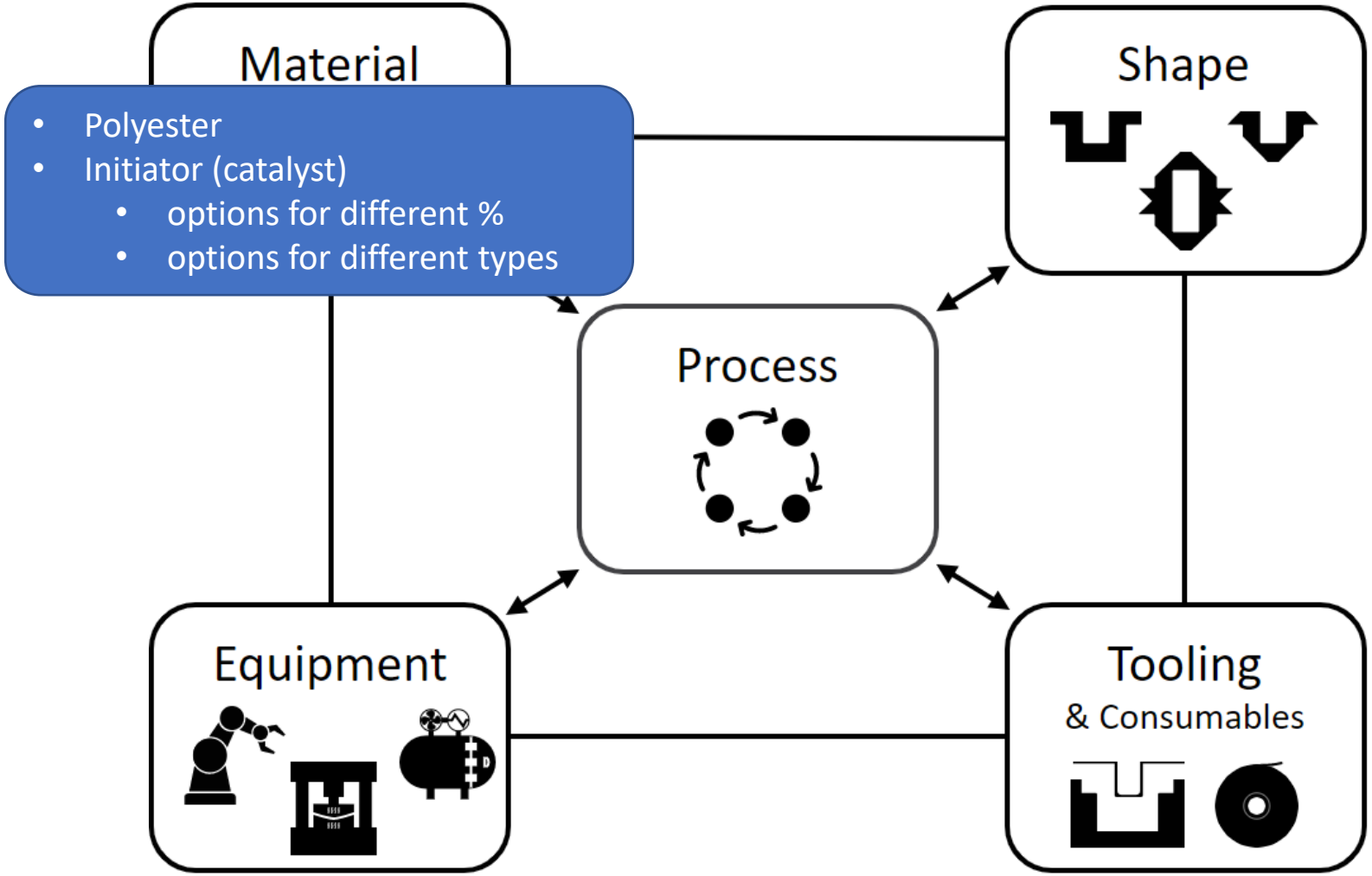

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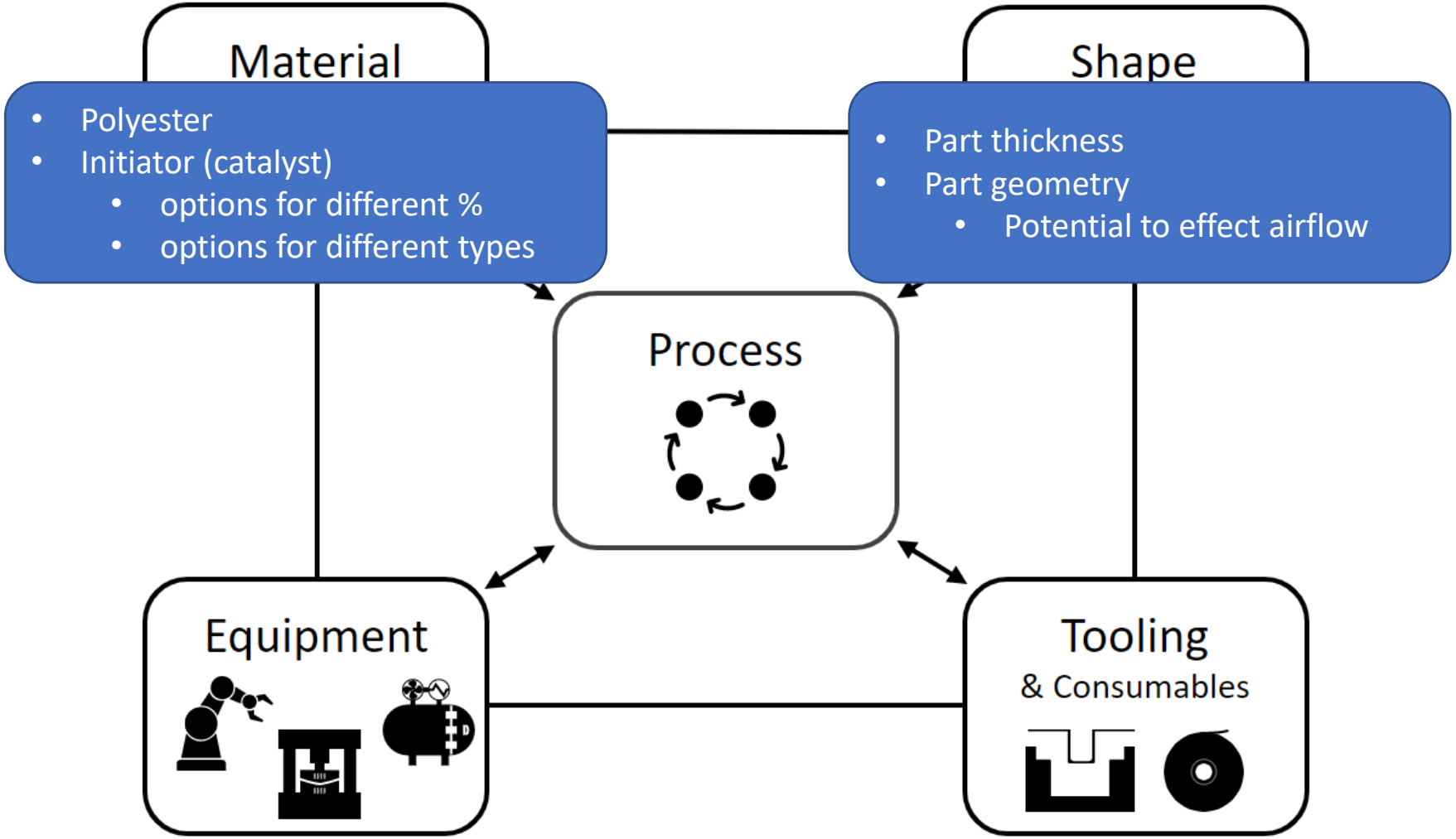

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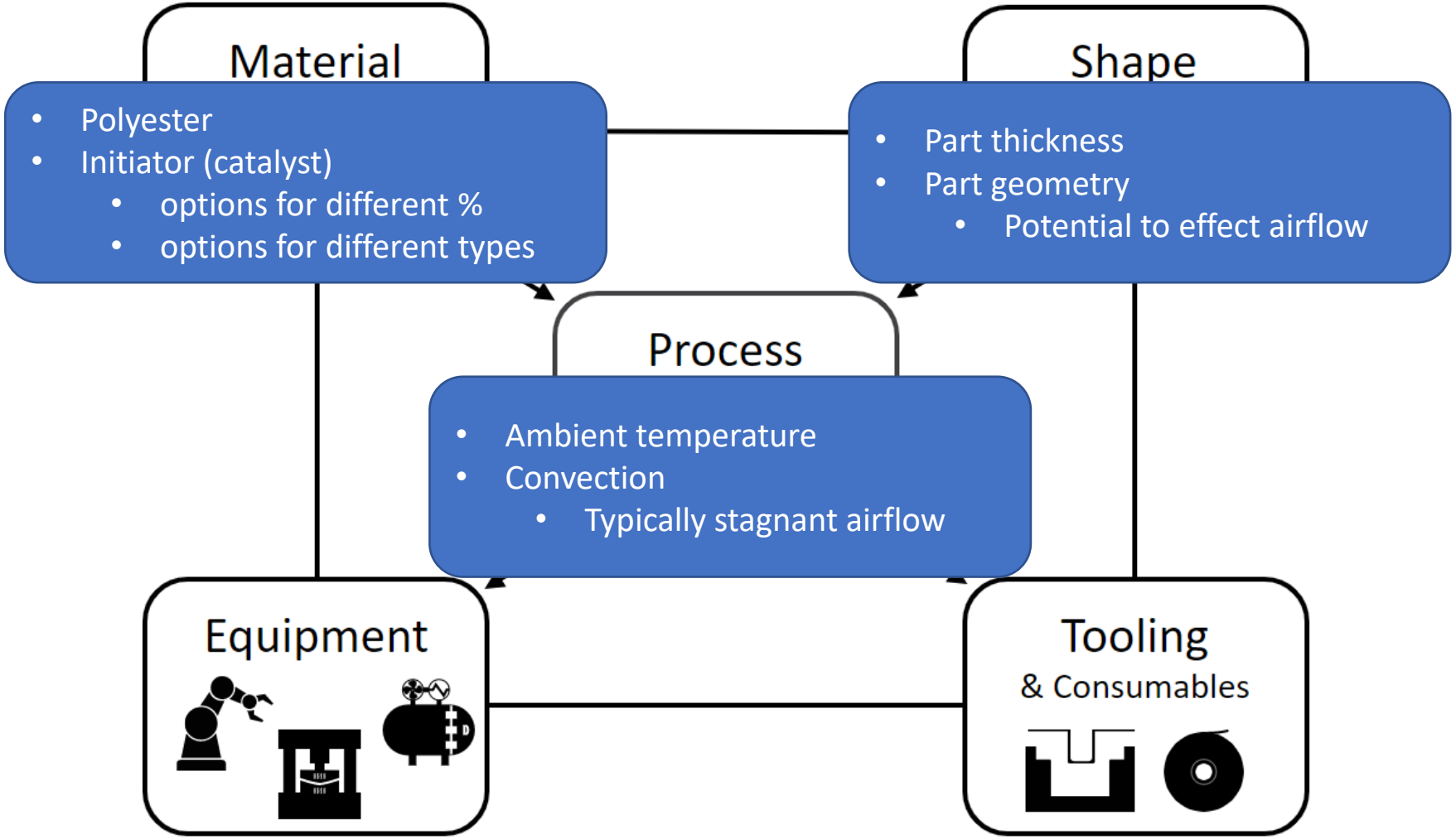

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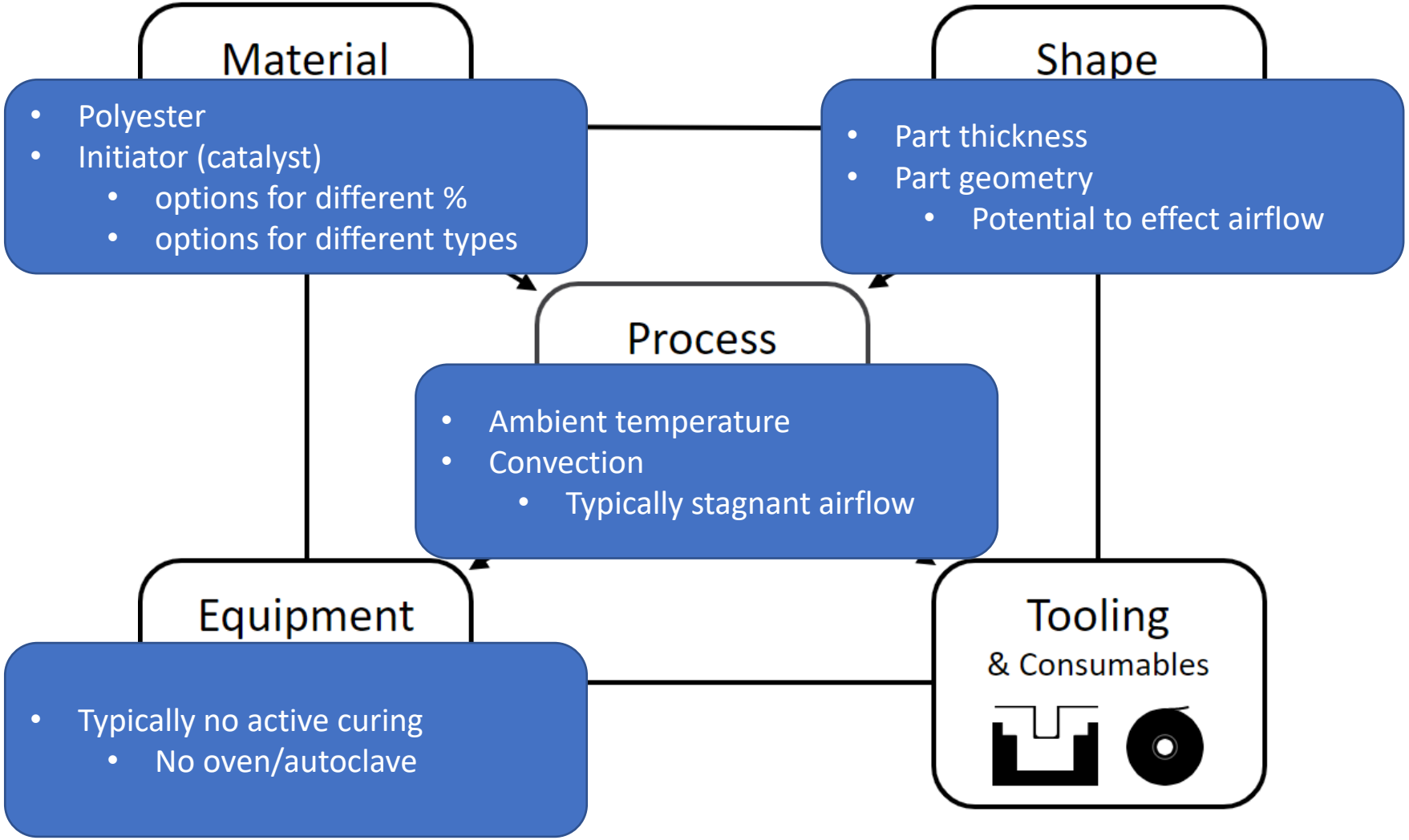

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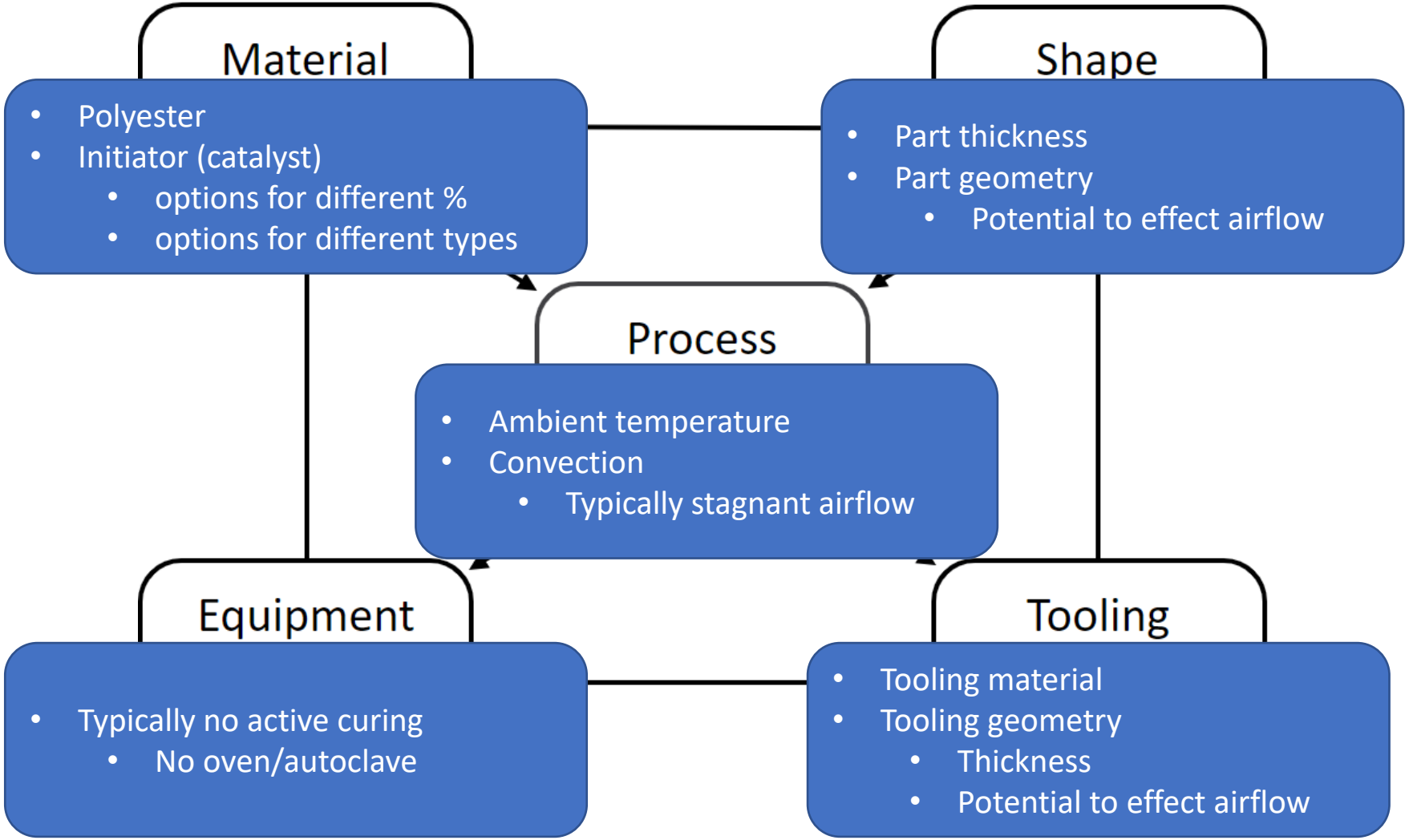
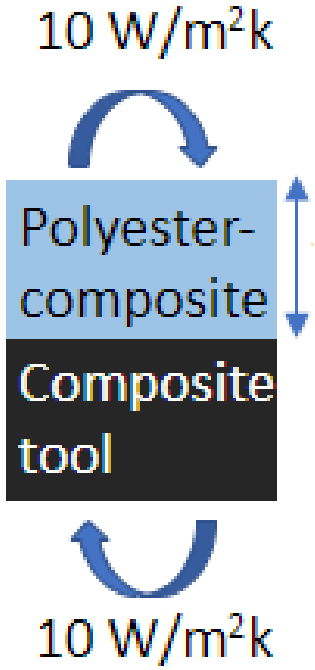


POLYESTER RESIN CURE SIMULATION

Unless otherwise stated:
6 mm composite part
Aropol polyester resin
1.25% MEKP
6 mm composite tool
h =10 W/m^{2}K
20^{o}C ambient air

- We'll use 1D simulation to explore various parameters:
  - Part thickness
  - Airflow (convection)
  - Tooling material
  - Tooling thickness



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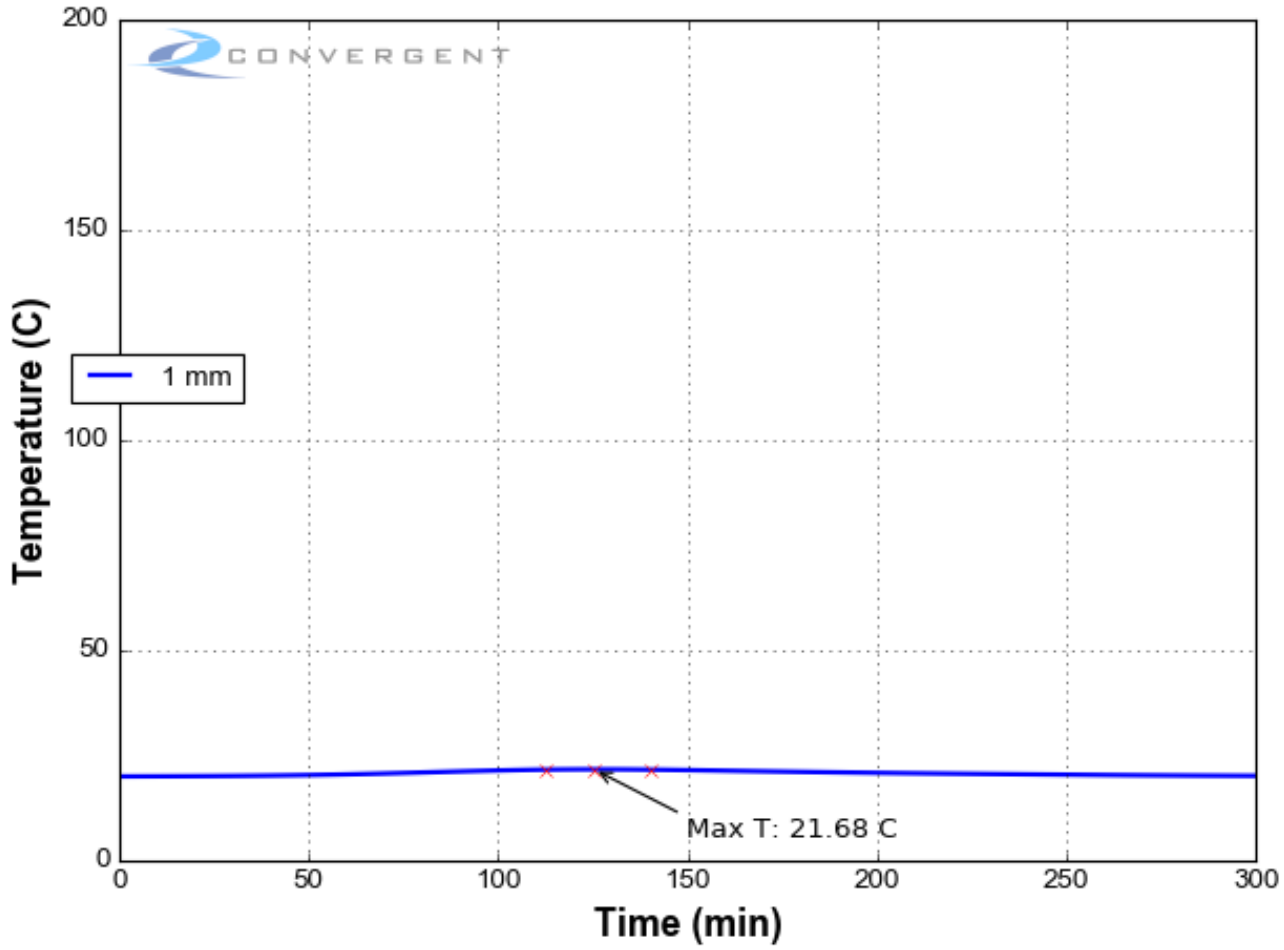

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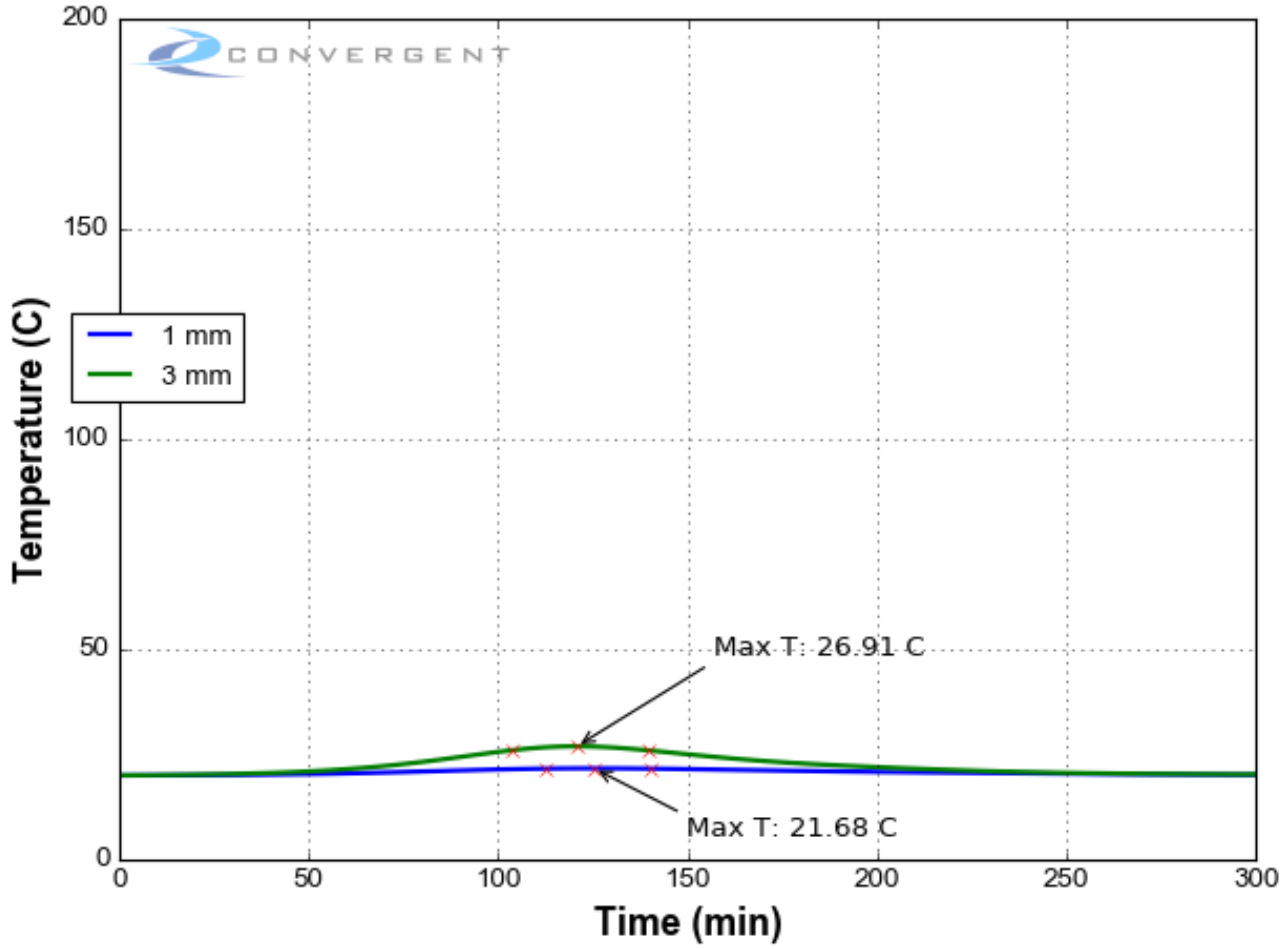

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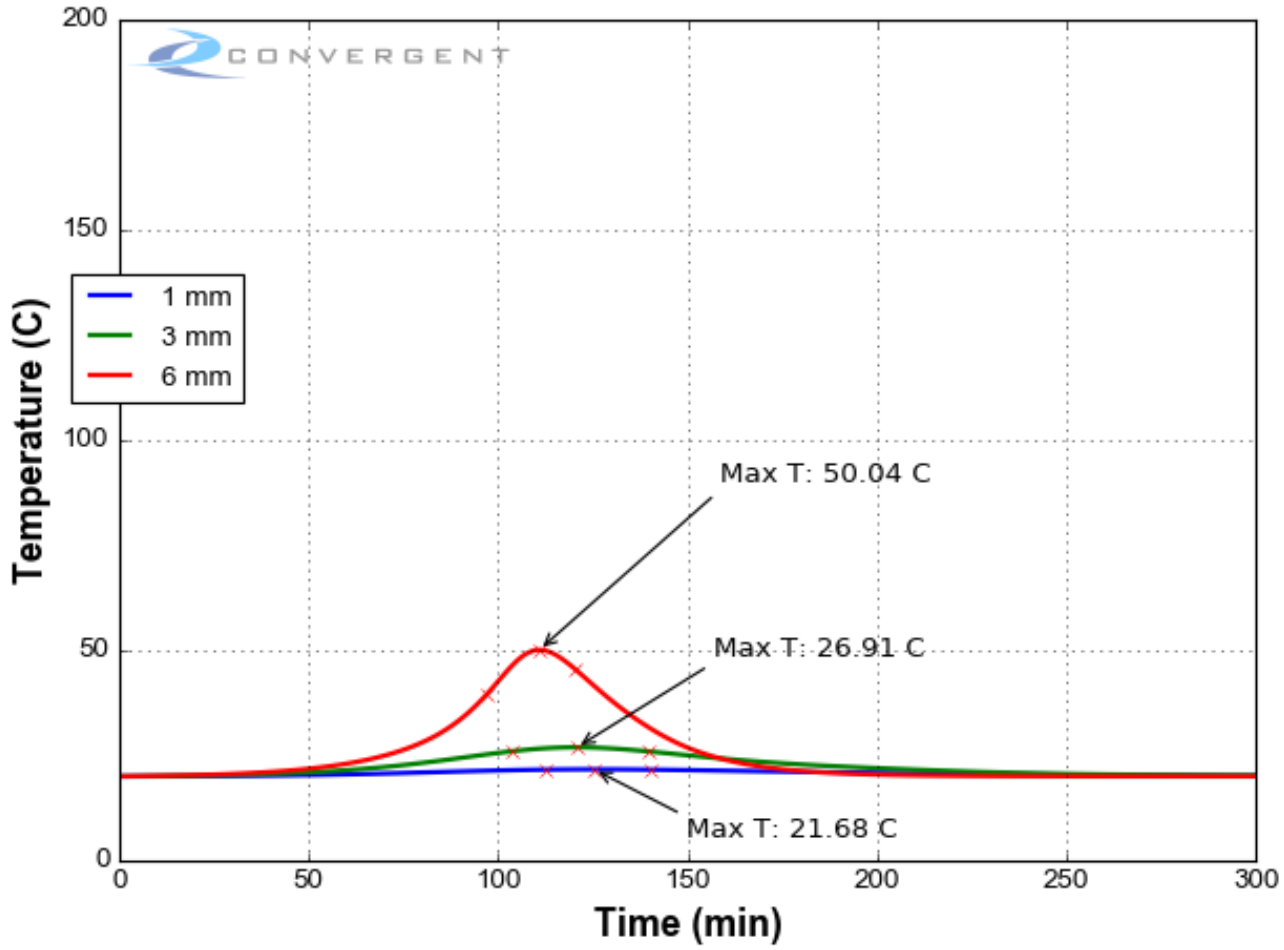

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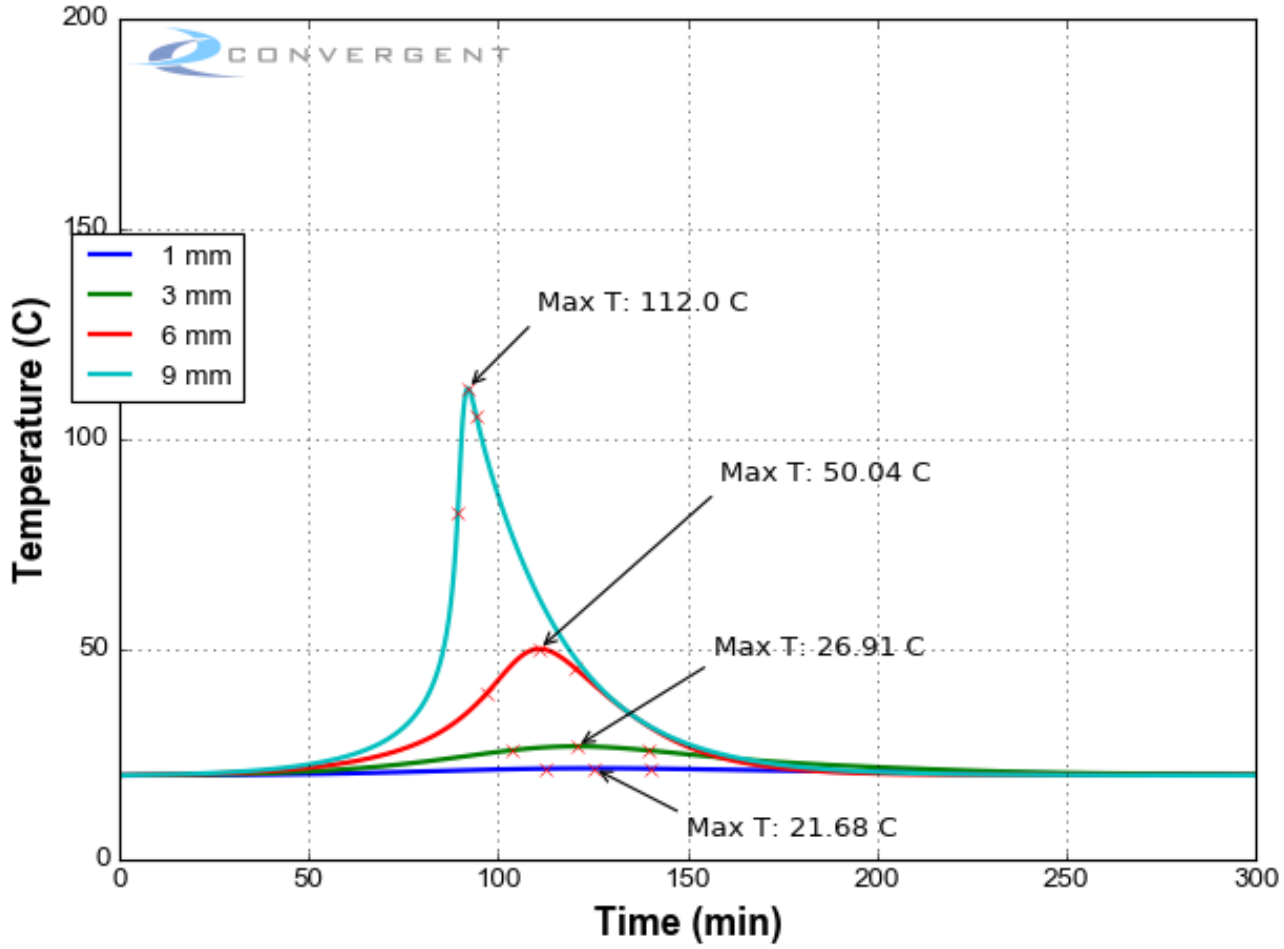

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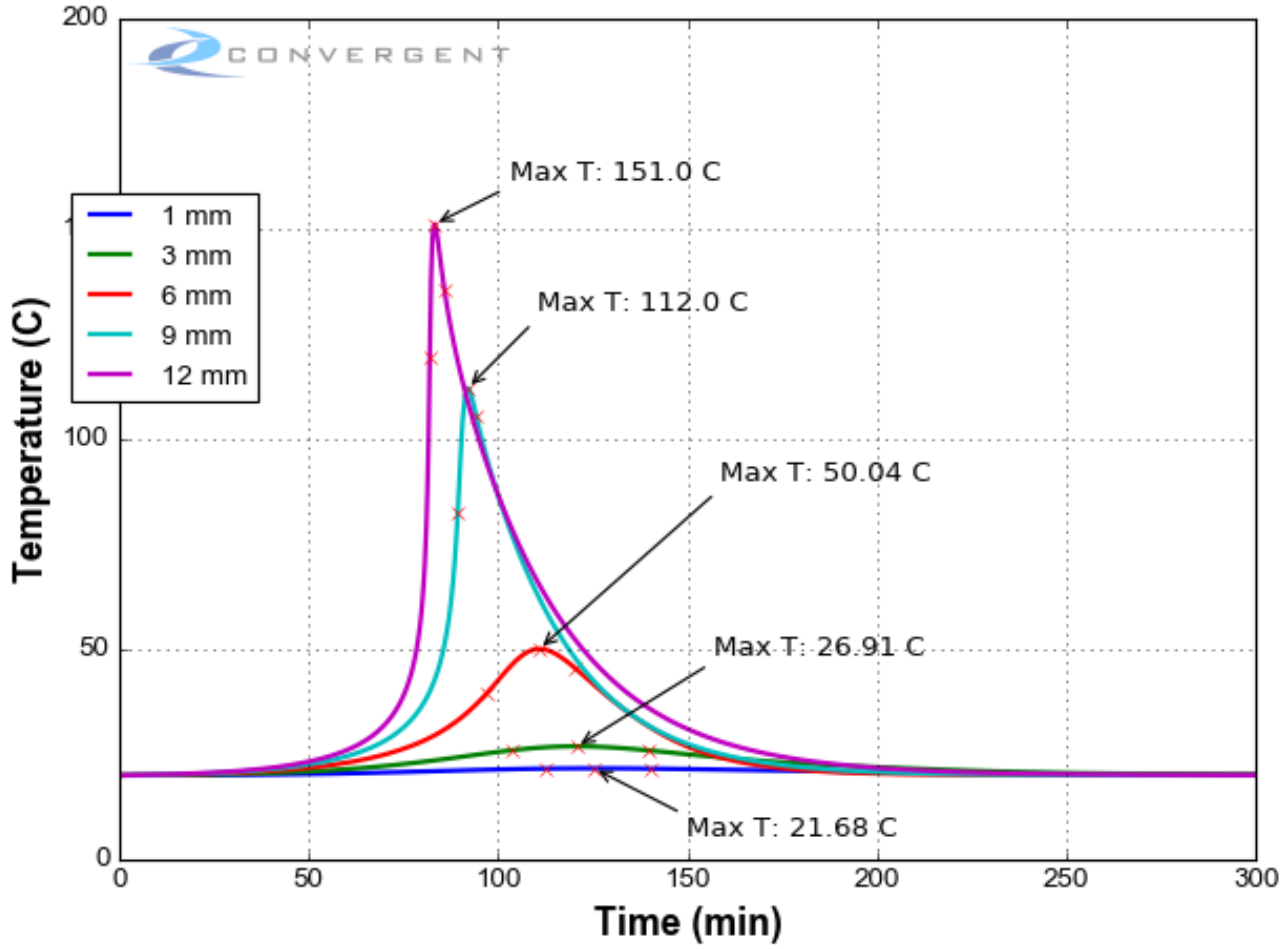

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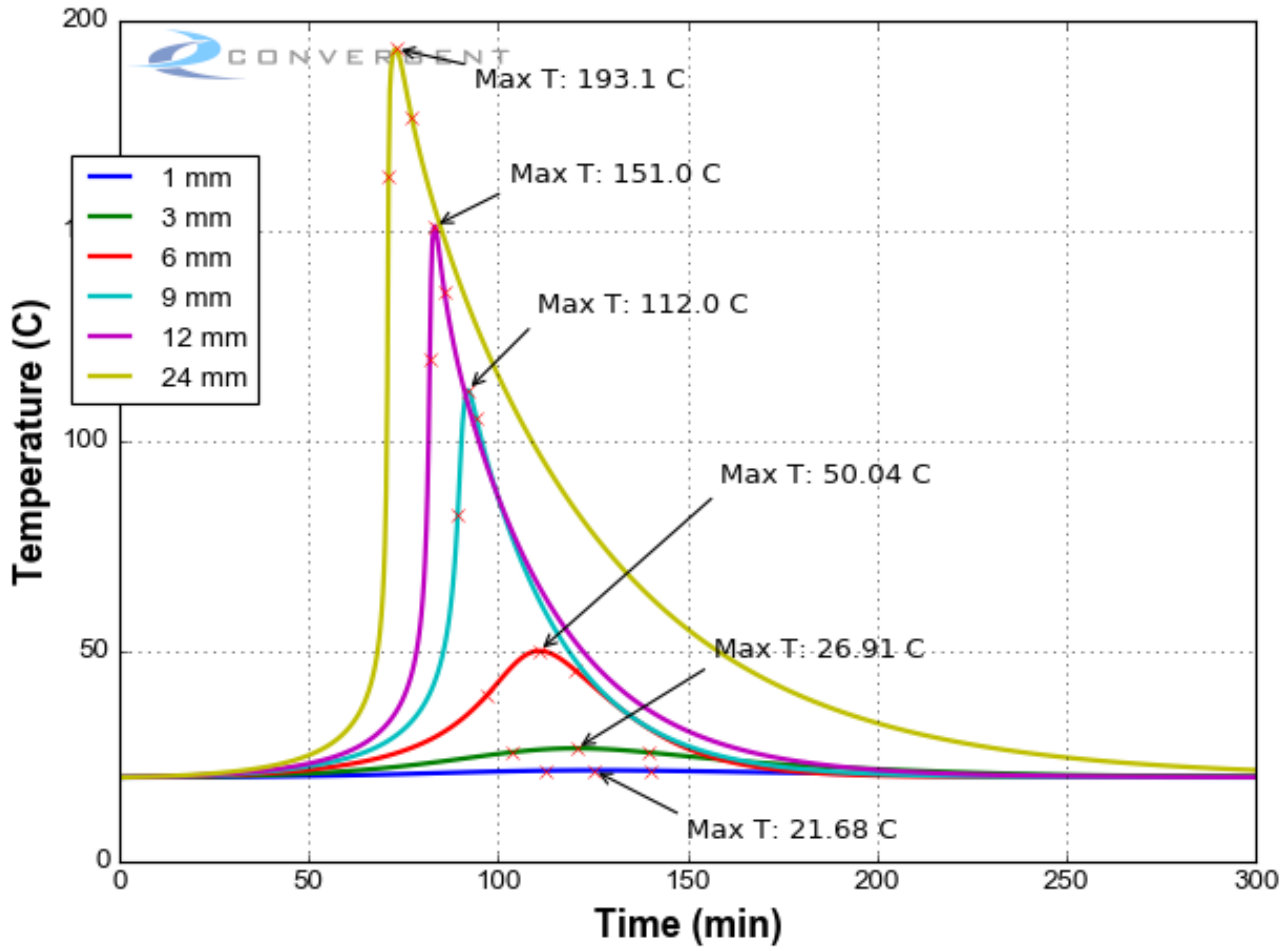

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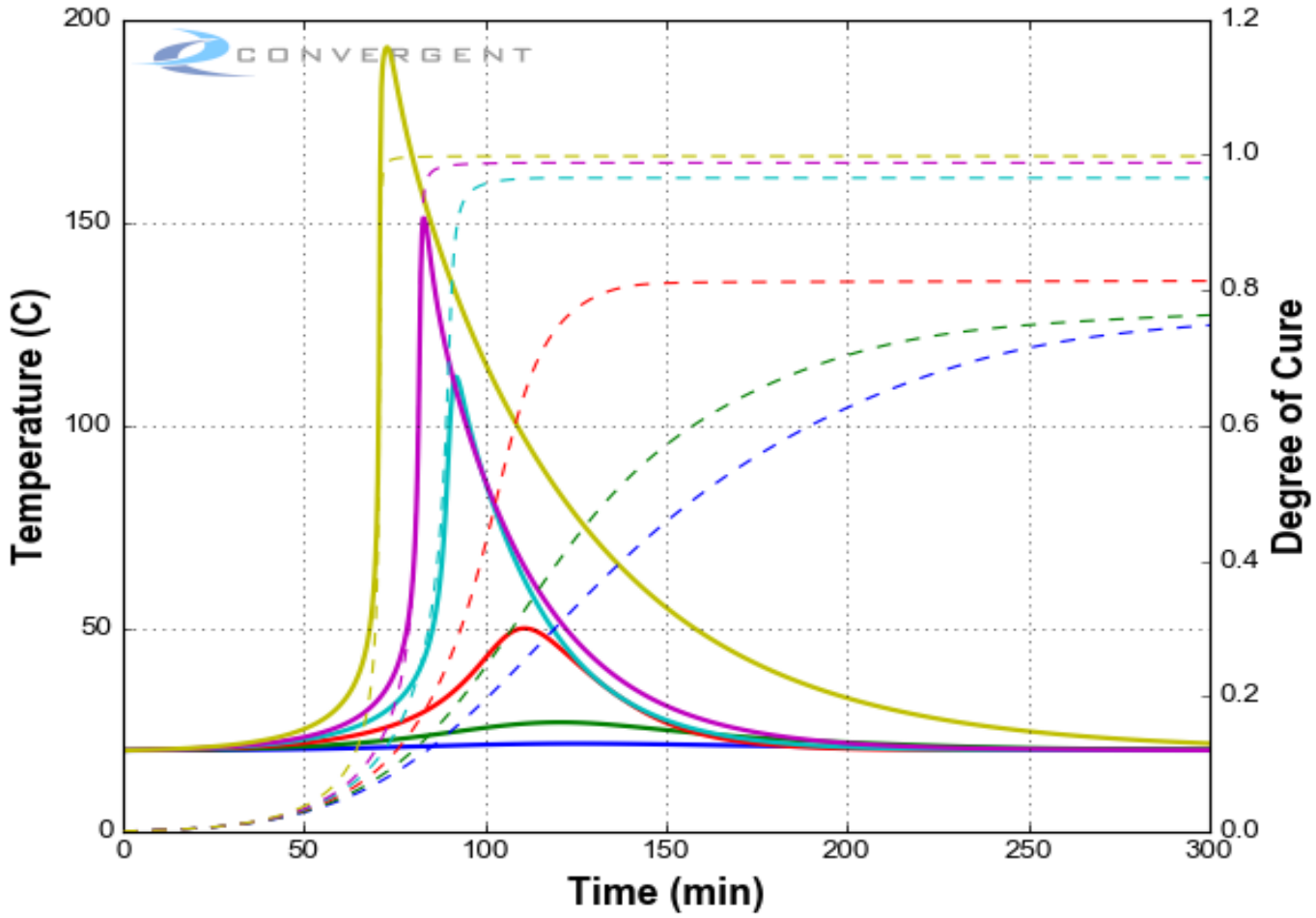

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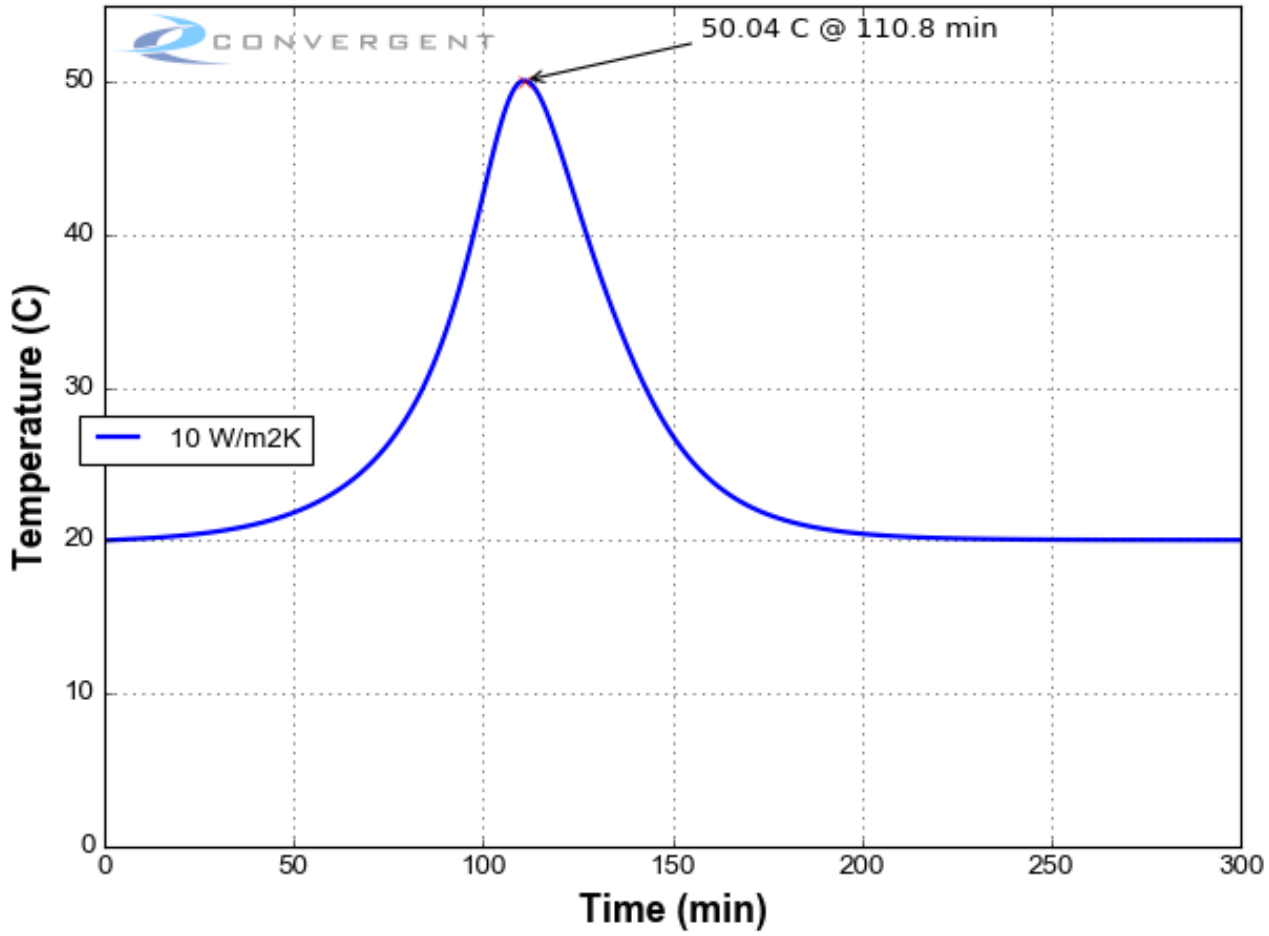

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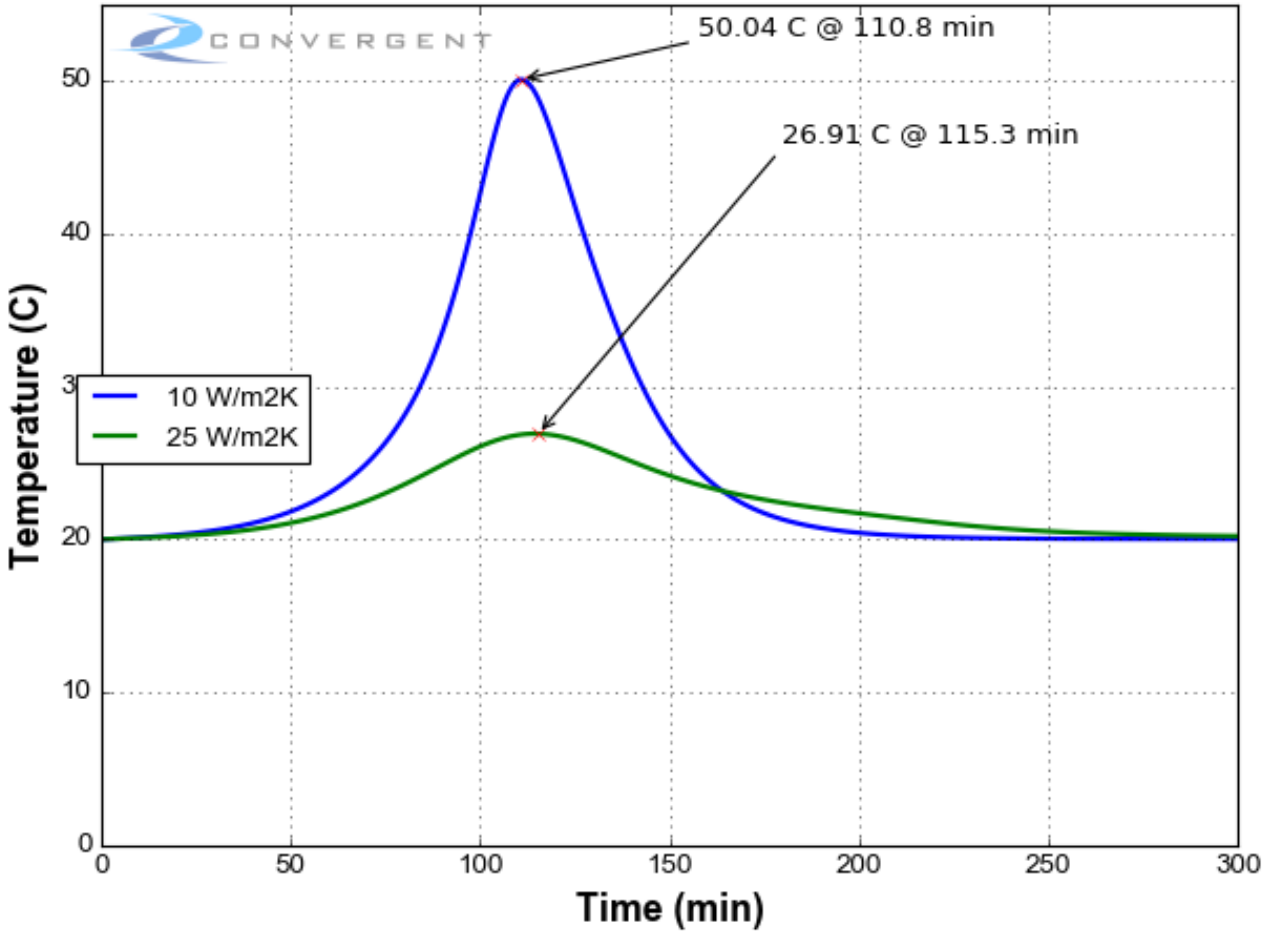

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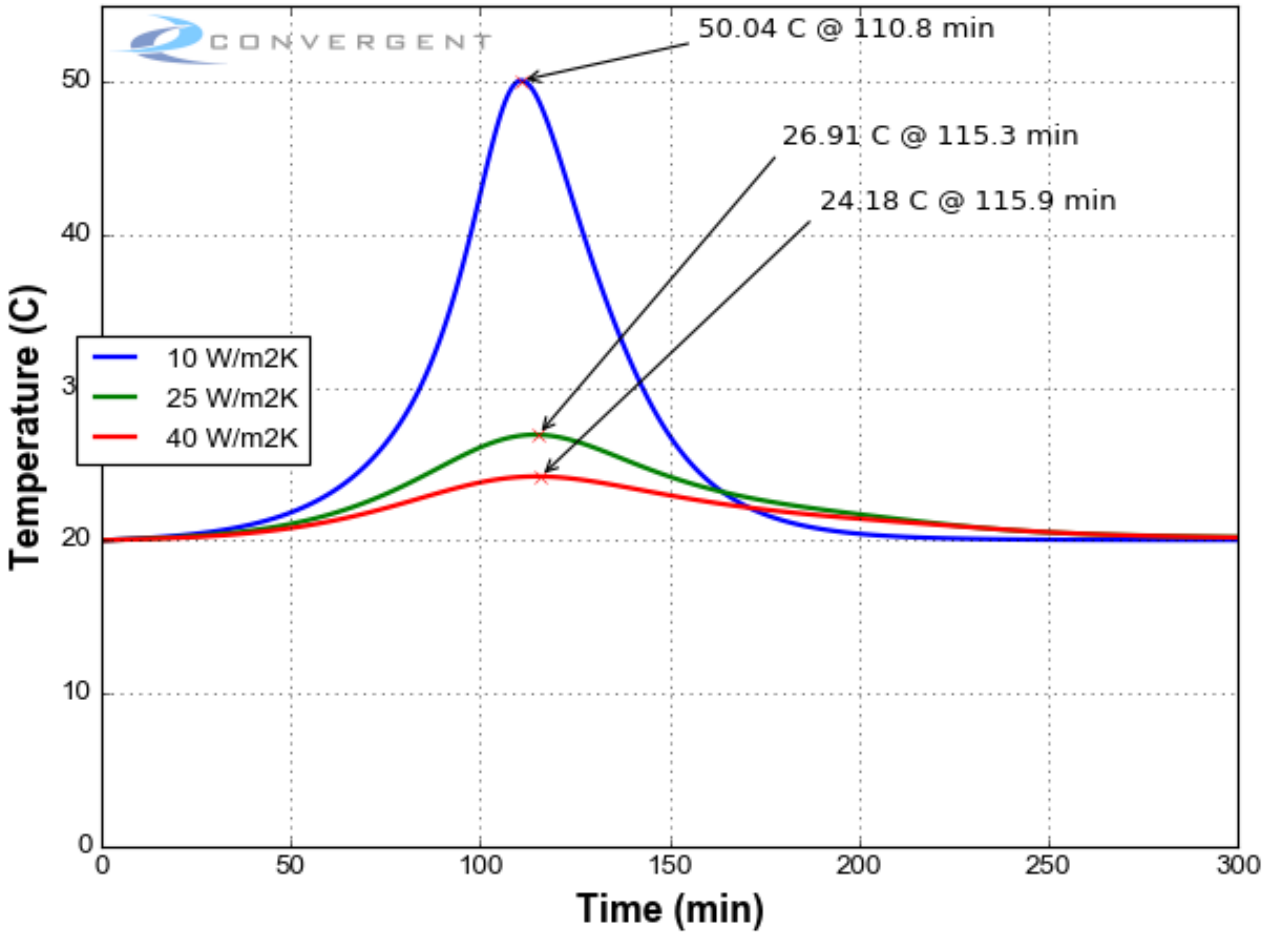

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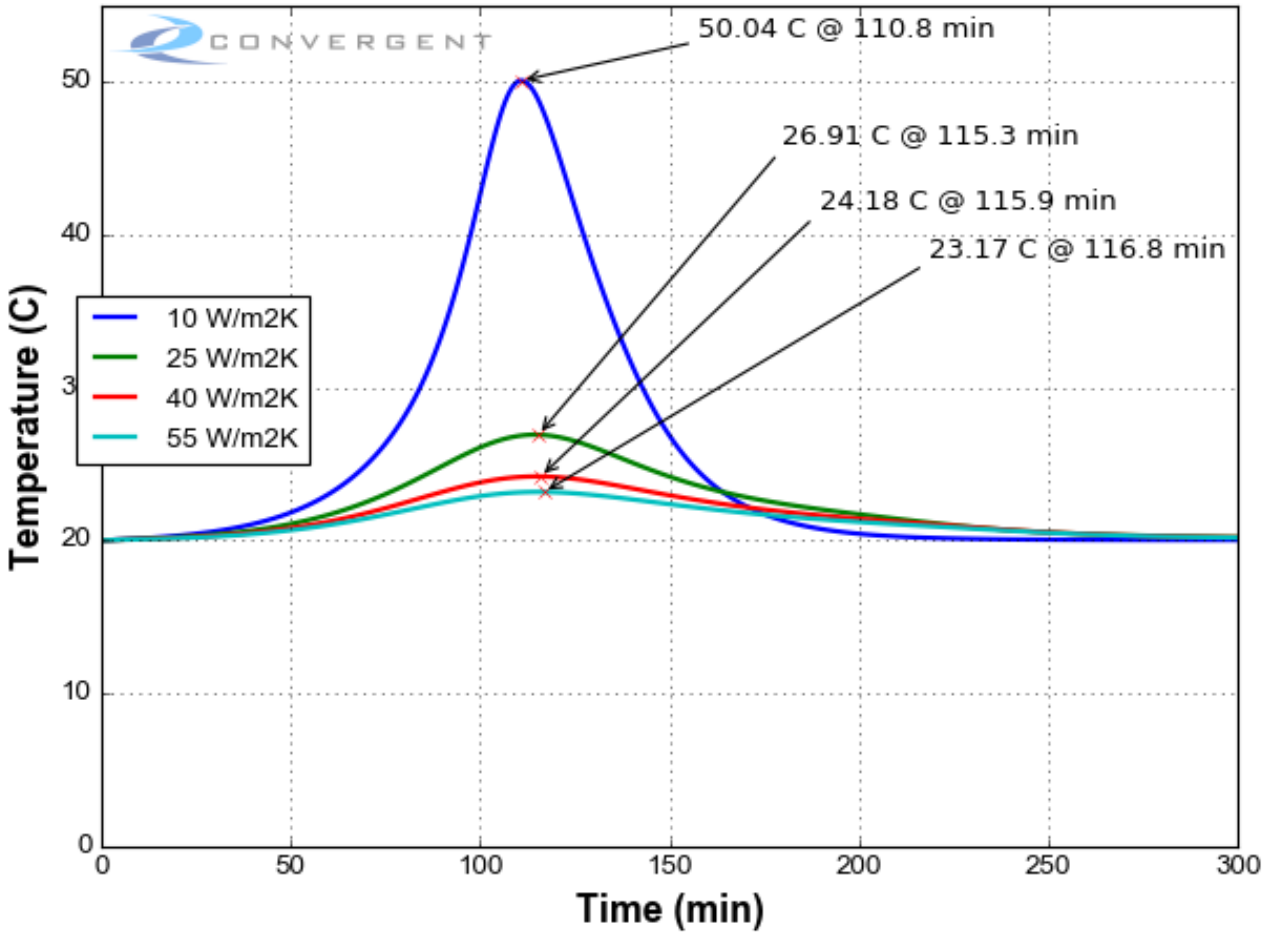

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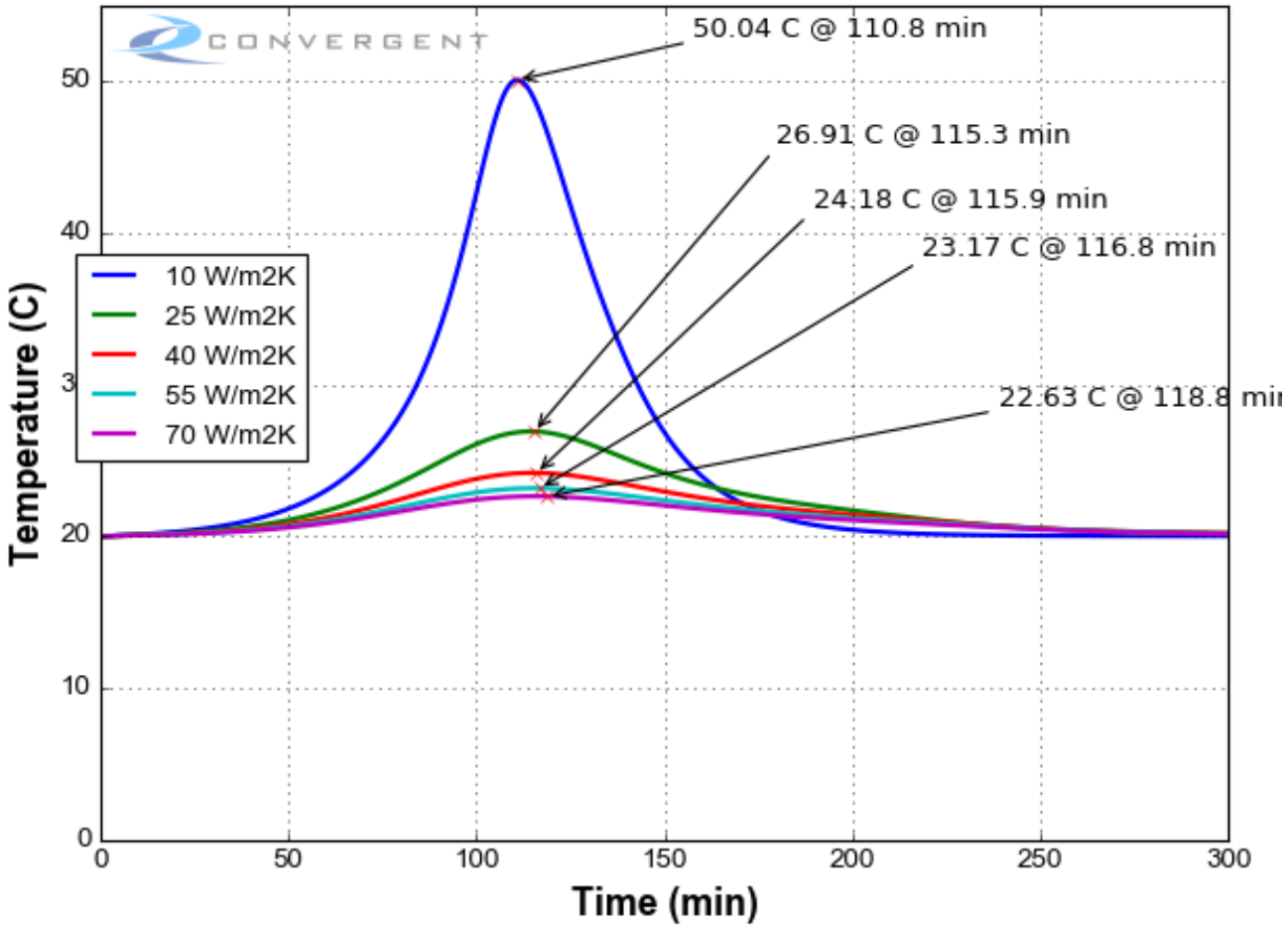

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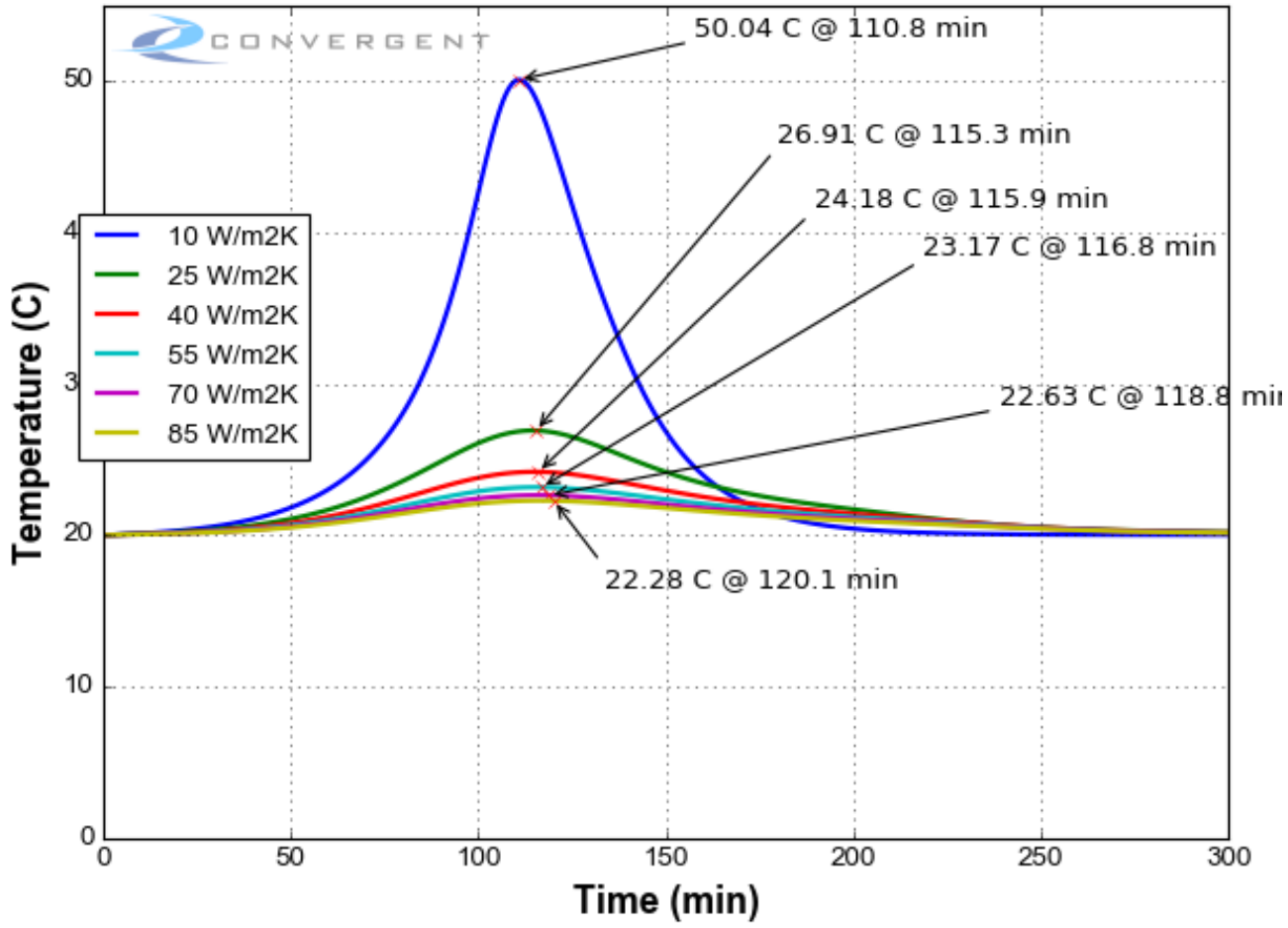

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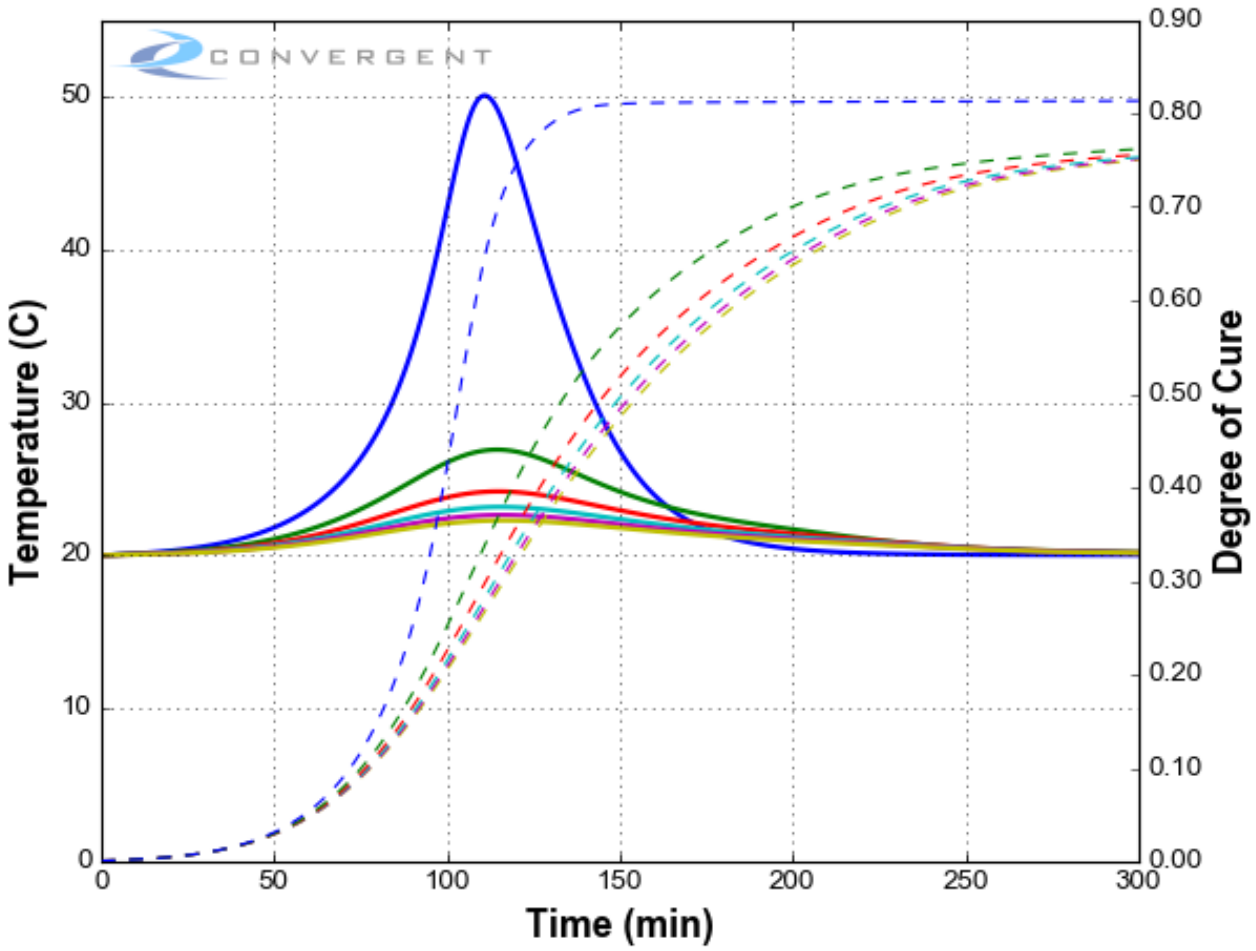
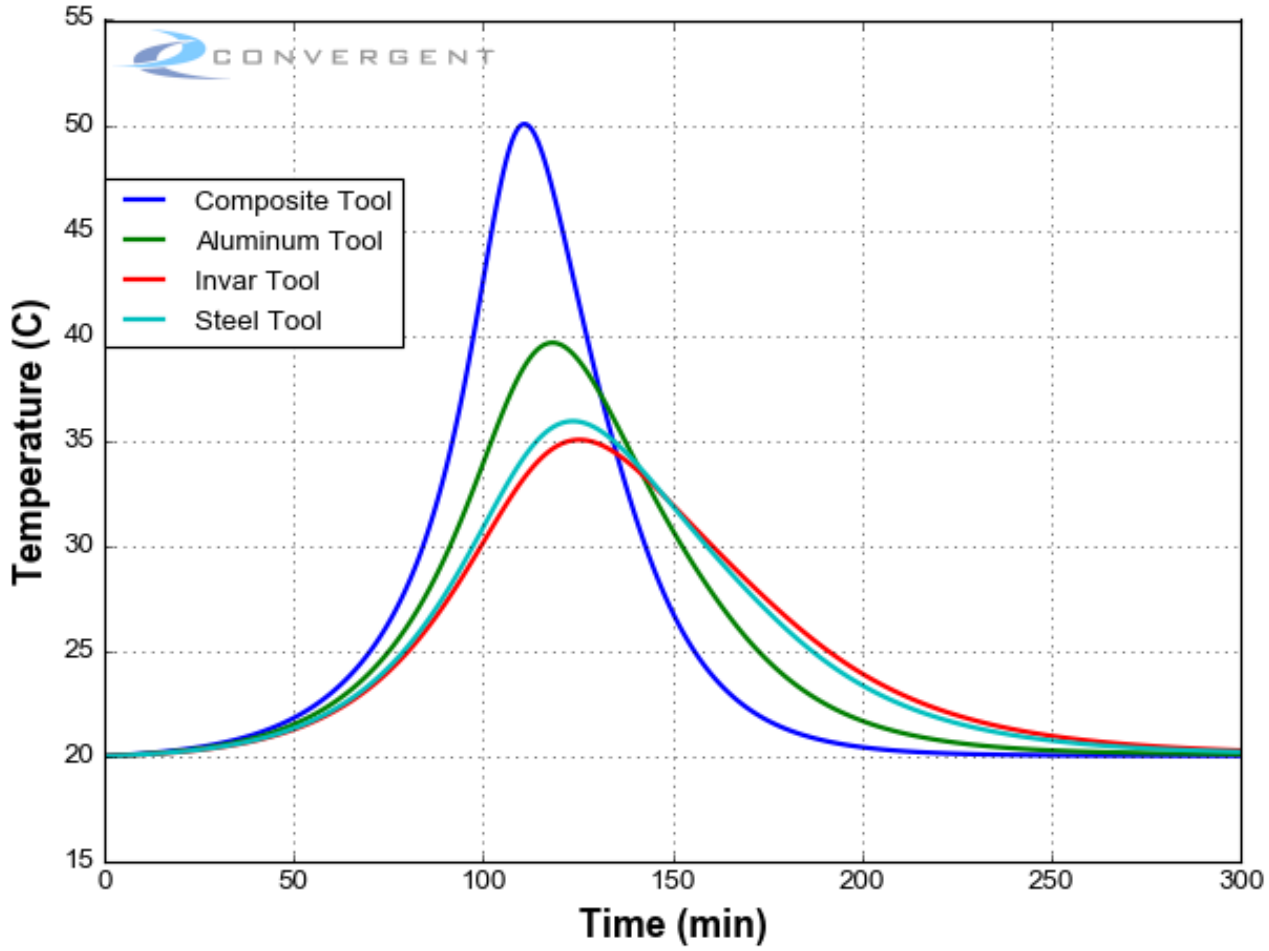


POLYESTER RESIN CURE SIMULATION

- Tooling Material



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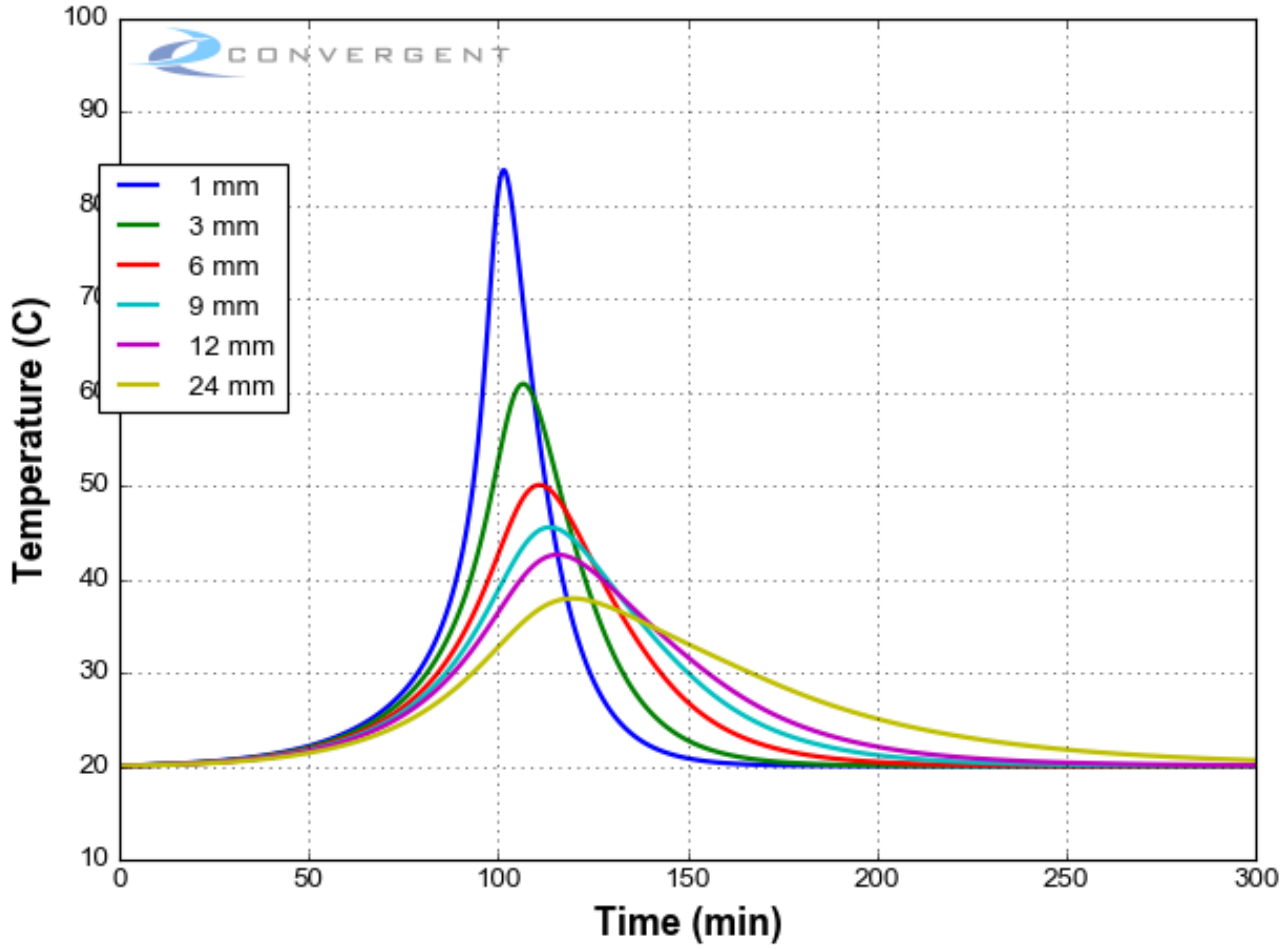
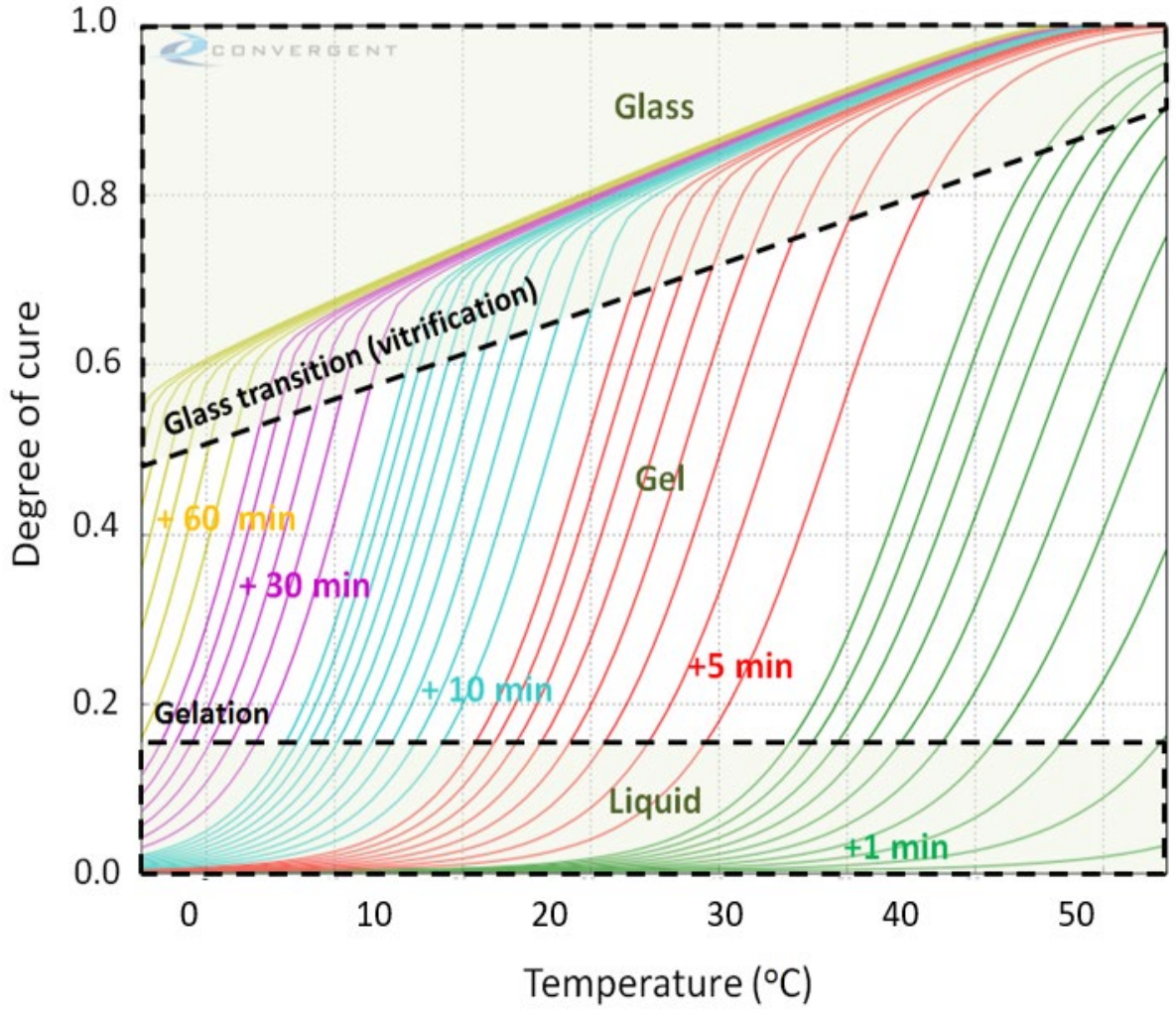
- Tooling thickness – Composite Tool



POLYESTER RESIN CURE SIMULATION

- We haven't discussed temperature yet…

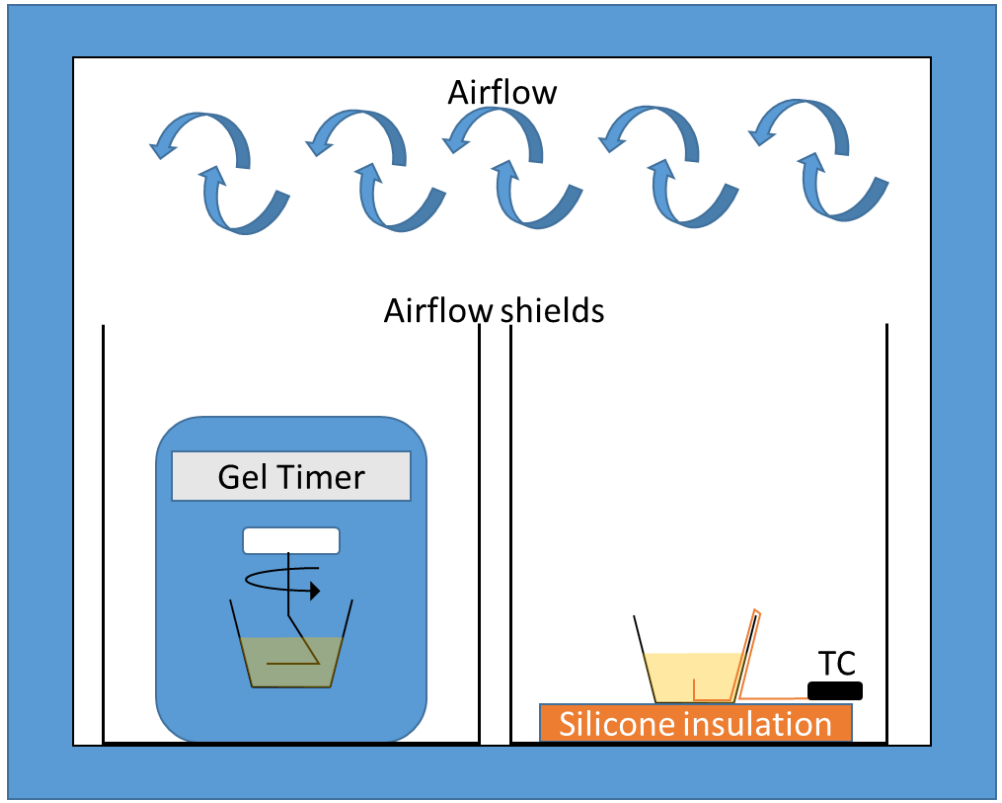


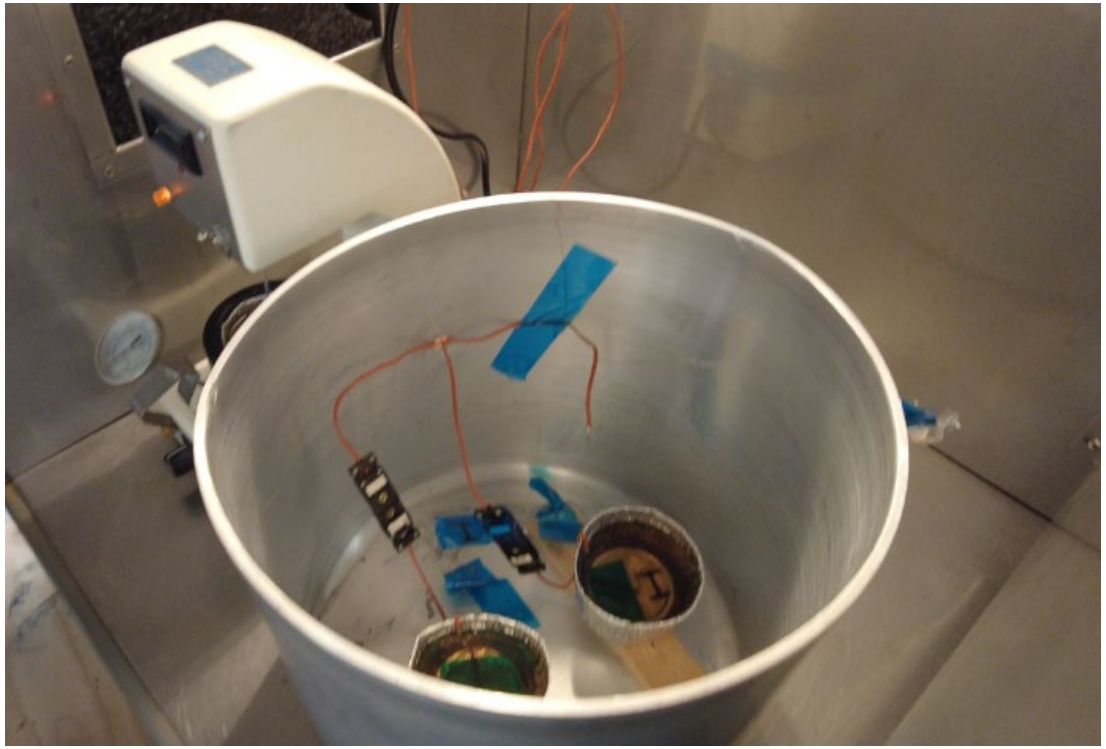
EXPERIMENTAL STUDY - EFFECT OF AMBIENT TEMPERATURE

- Material:
  - Polyester material: Aropol CL 70502-25 Resin & Luperox DDM-9 Initiator 1.25 Vol%

- Method:
  - 28.8 g of resin mixed and placed in an aluminum cup (thickness of 12.7 mm), repeated X2
  - One cup placed in an environmental chamber
  - One cup placed in gel timer, that was also in the environmental chamber
  - Thermocouple placed at the centre of the resin to log temperature data
  - Thermocouple used to record ambient temperature
  - Samples held at the following ambient temperatures:
    - 0 °C
    - 6 °C
    - 10 °C
    - 14 °C
    - 18 °C
    - 22 °C
    - 26 °C

EXPERIMENTAL STUDY - EFFECT OF AMBIENT TEMPERATURE





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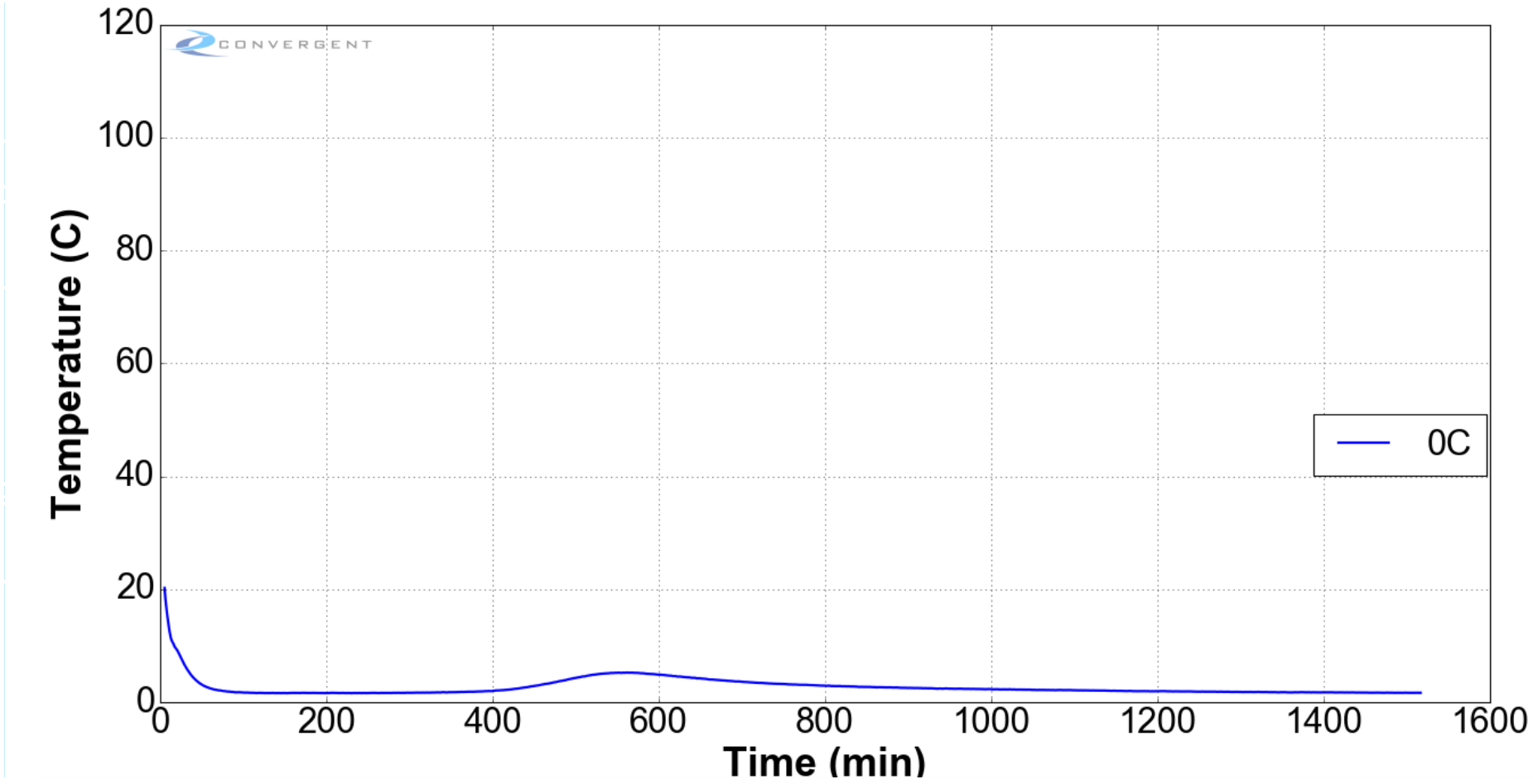

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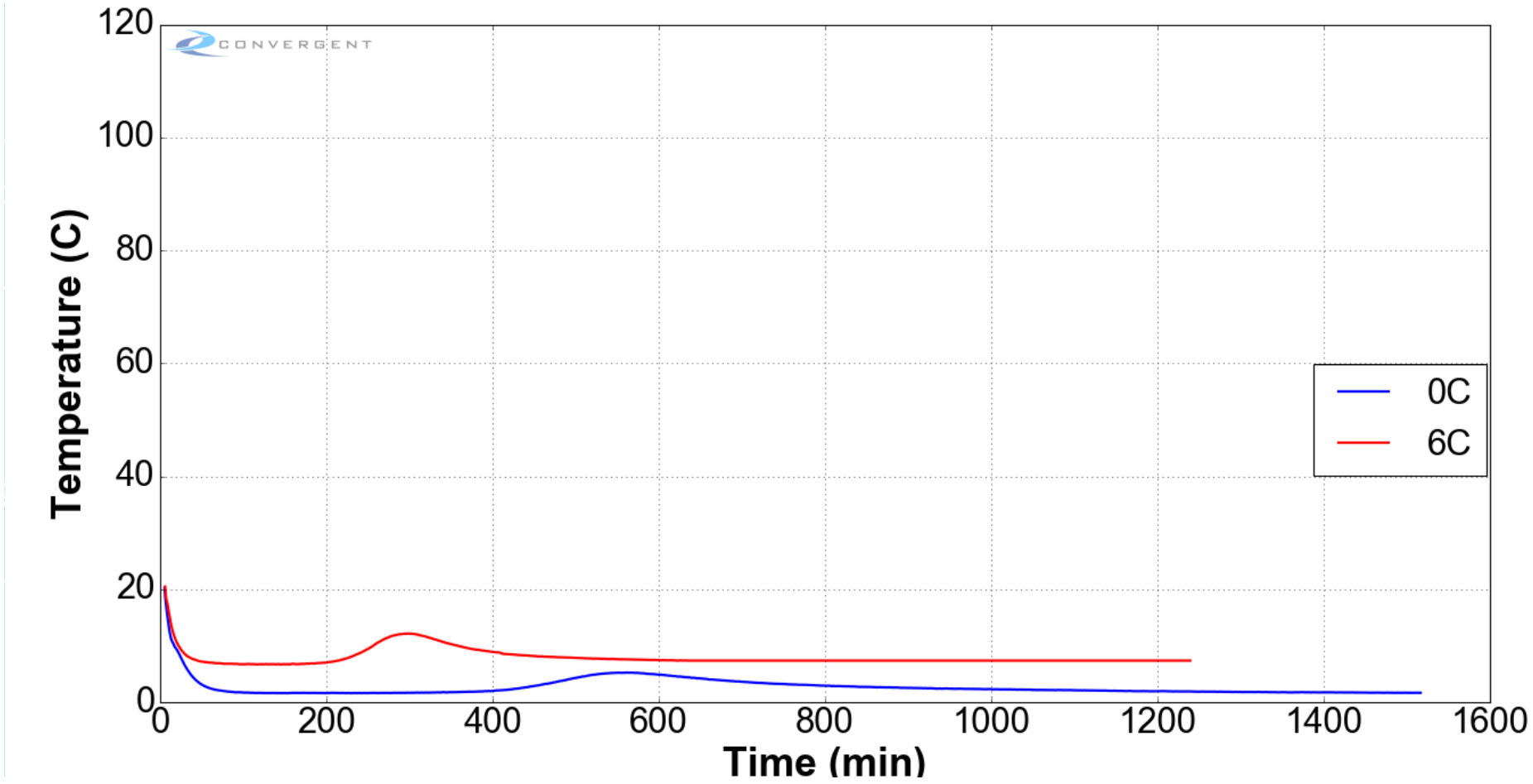

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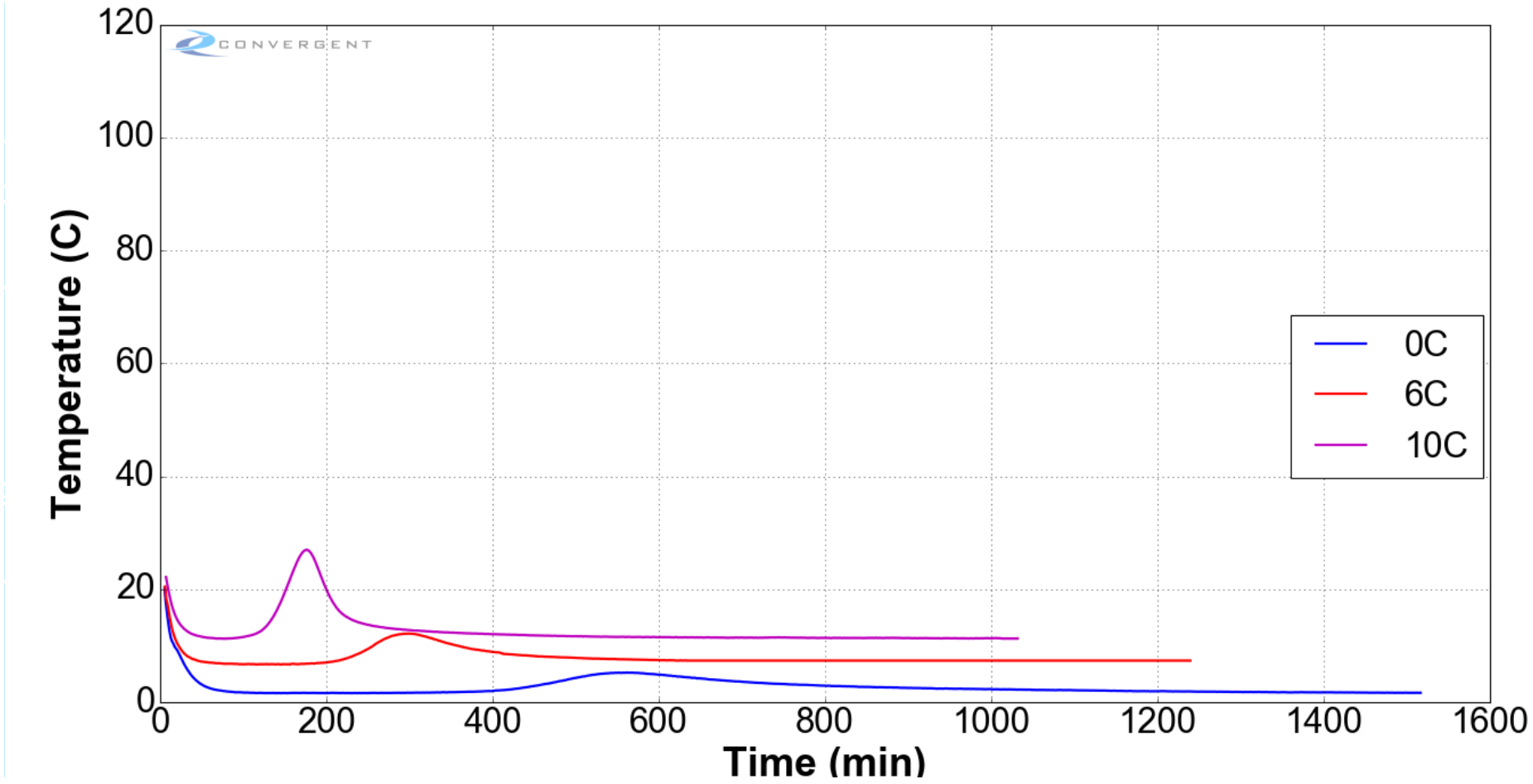

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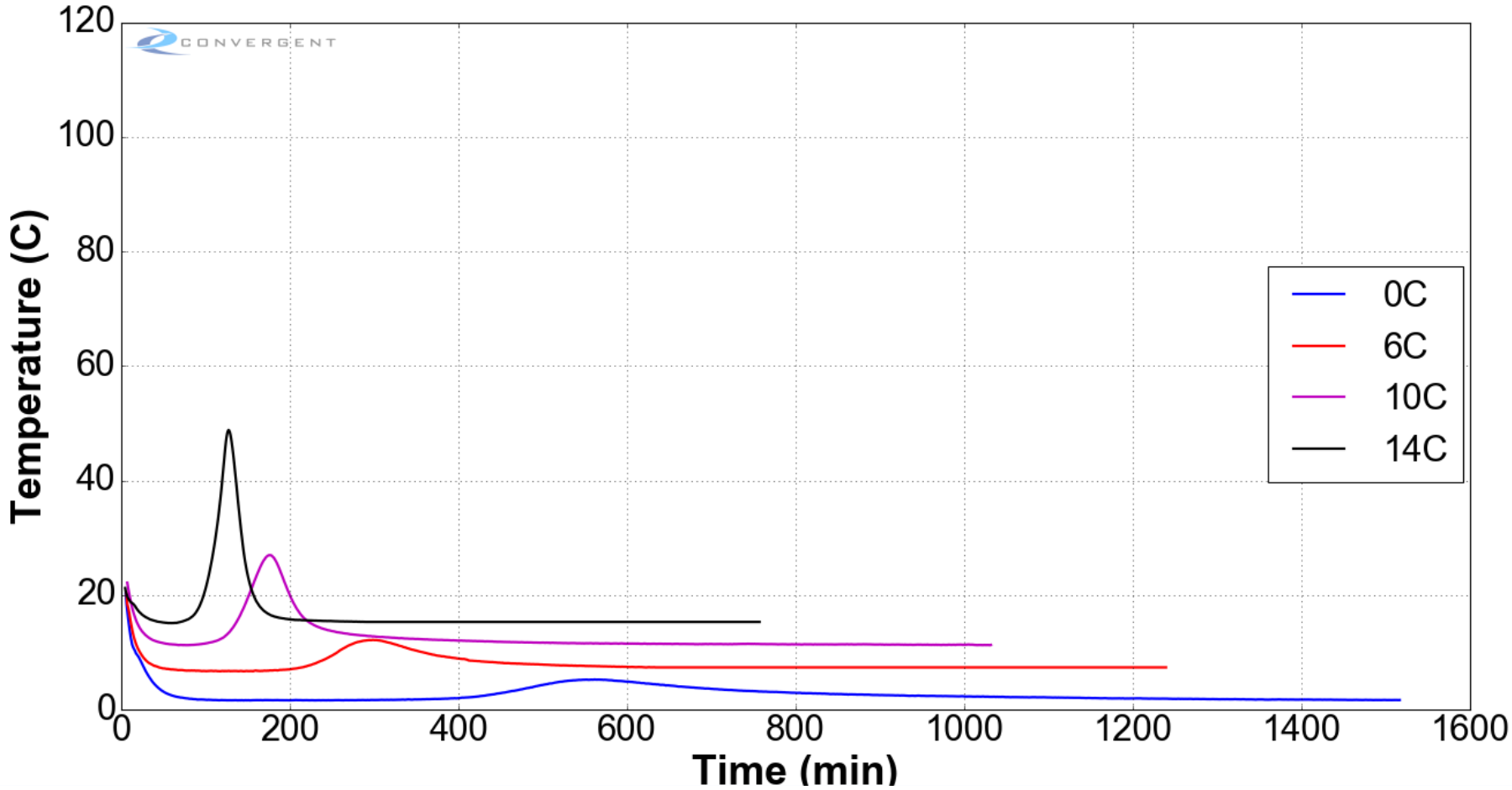

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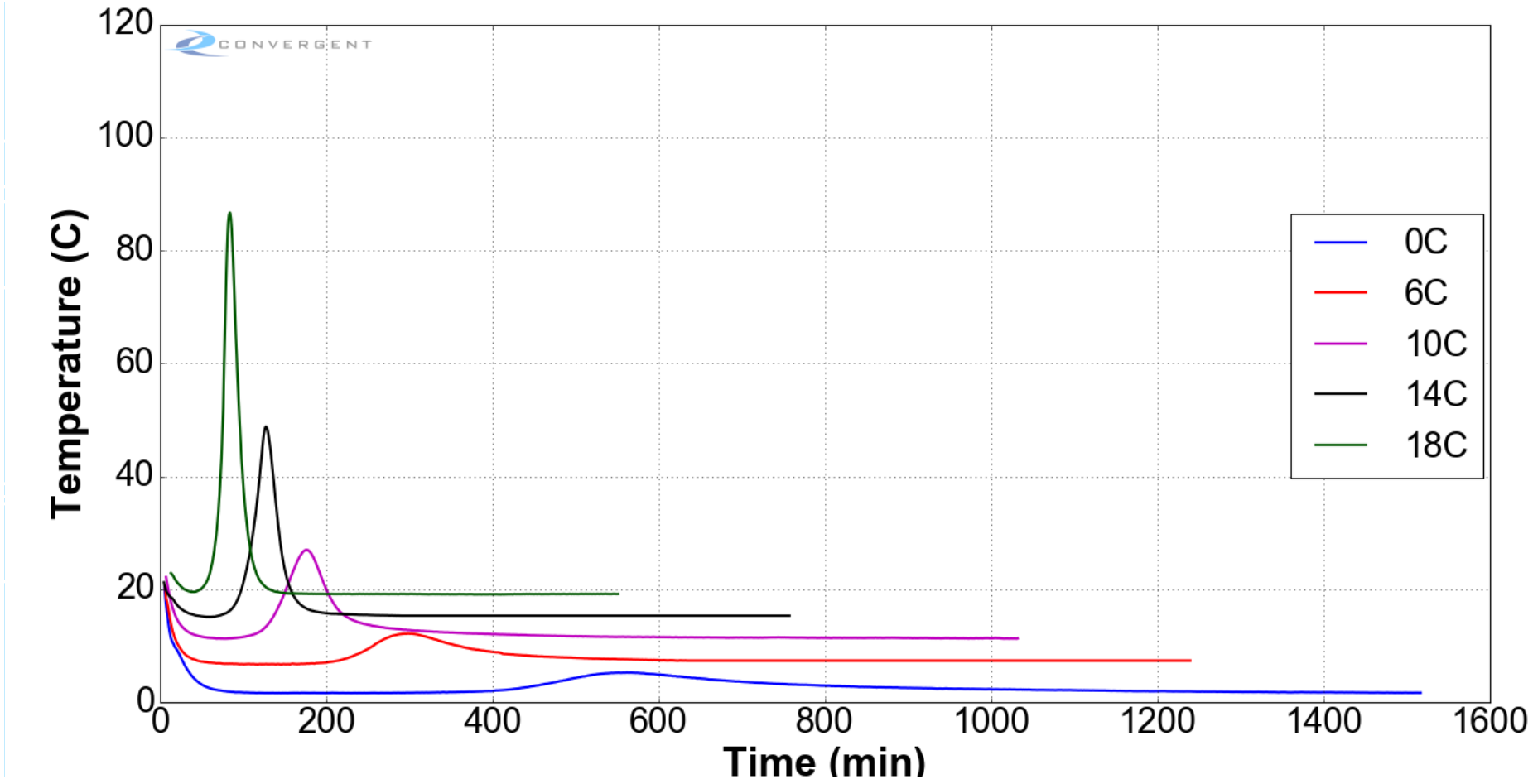

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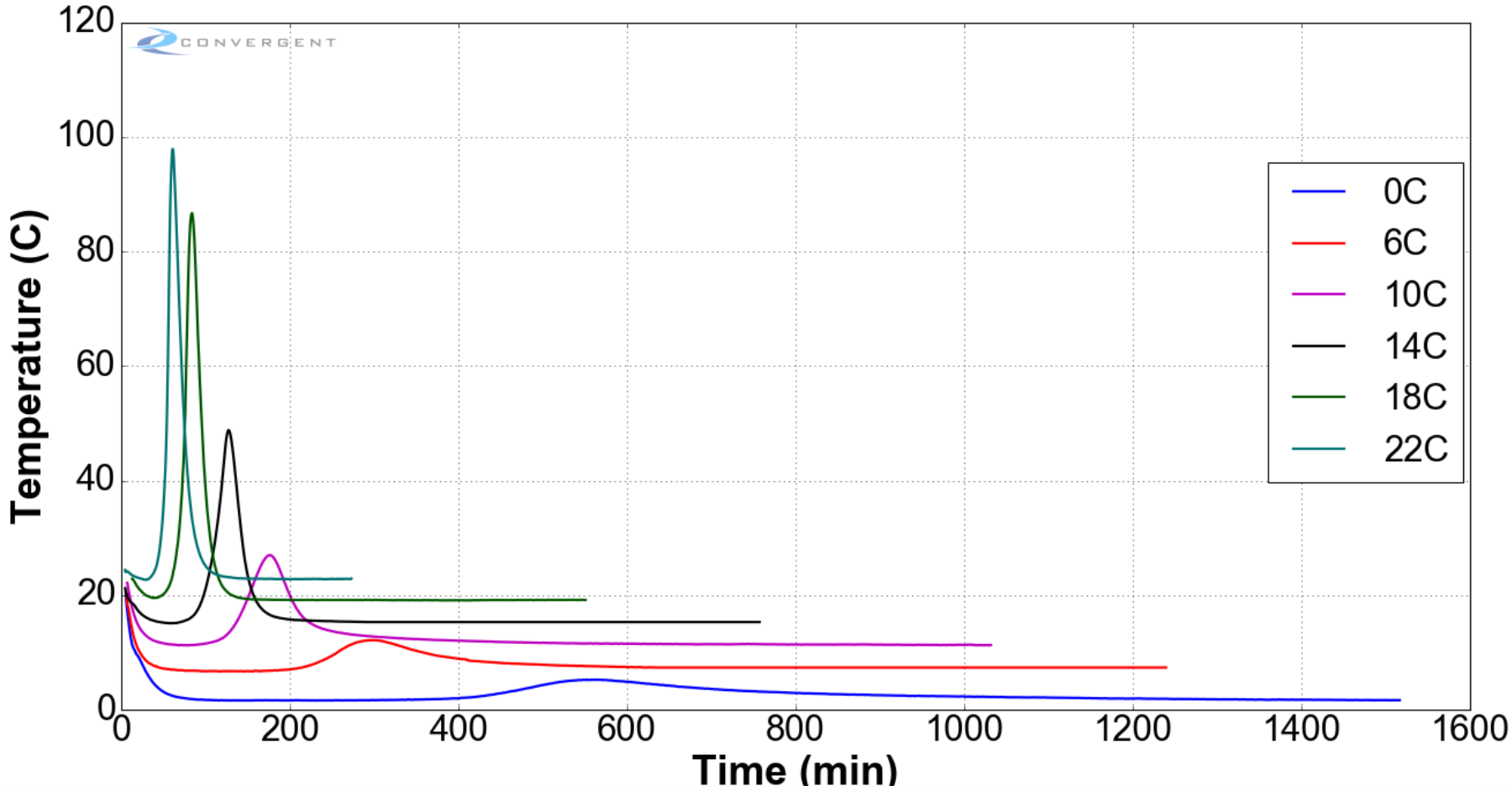

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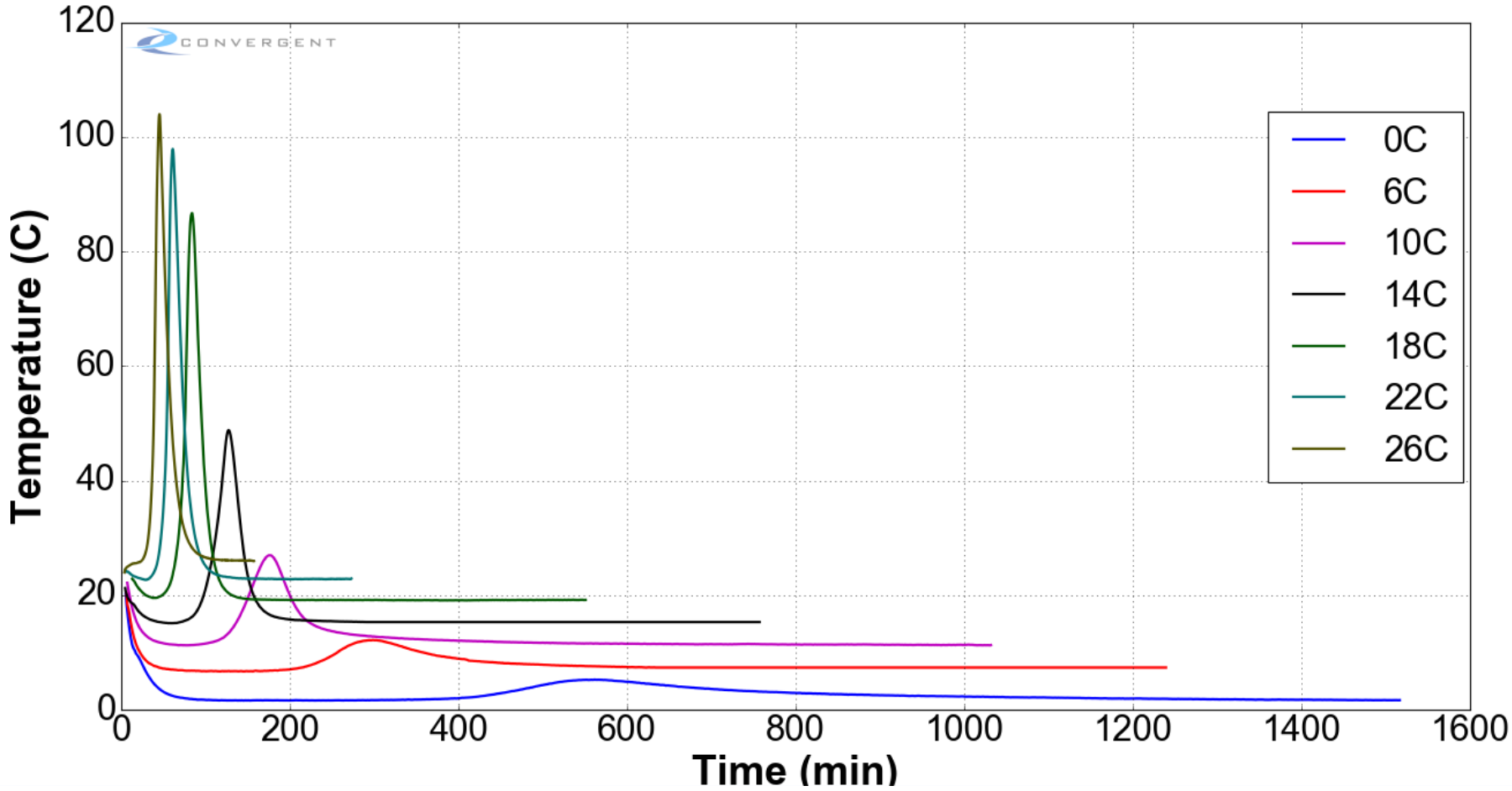

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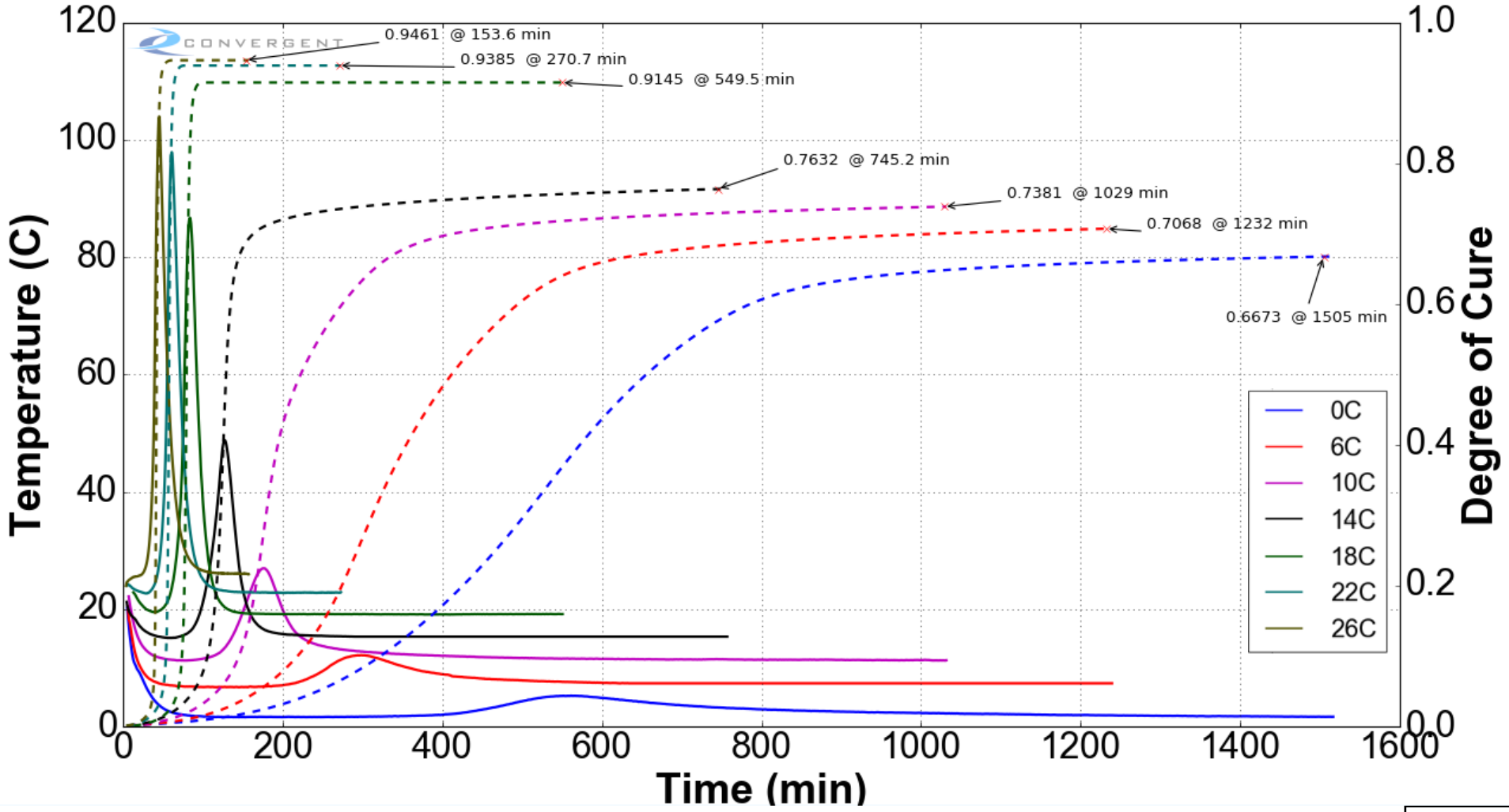

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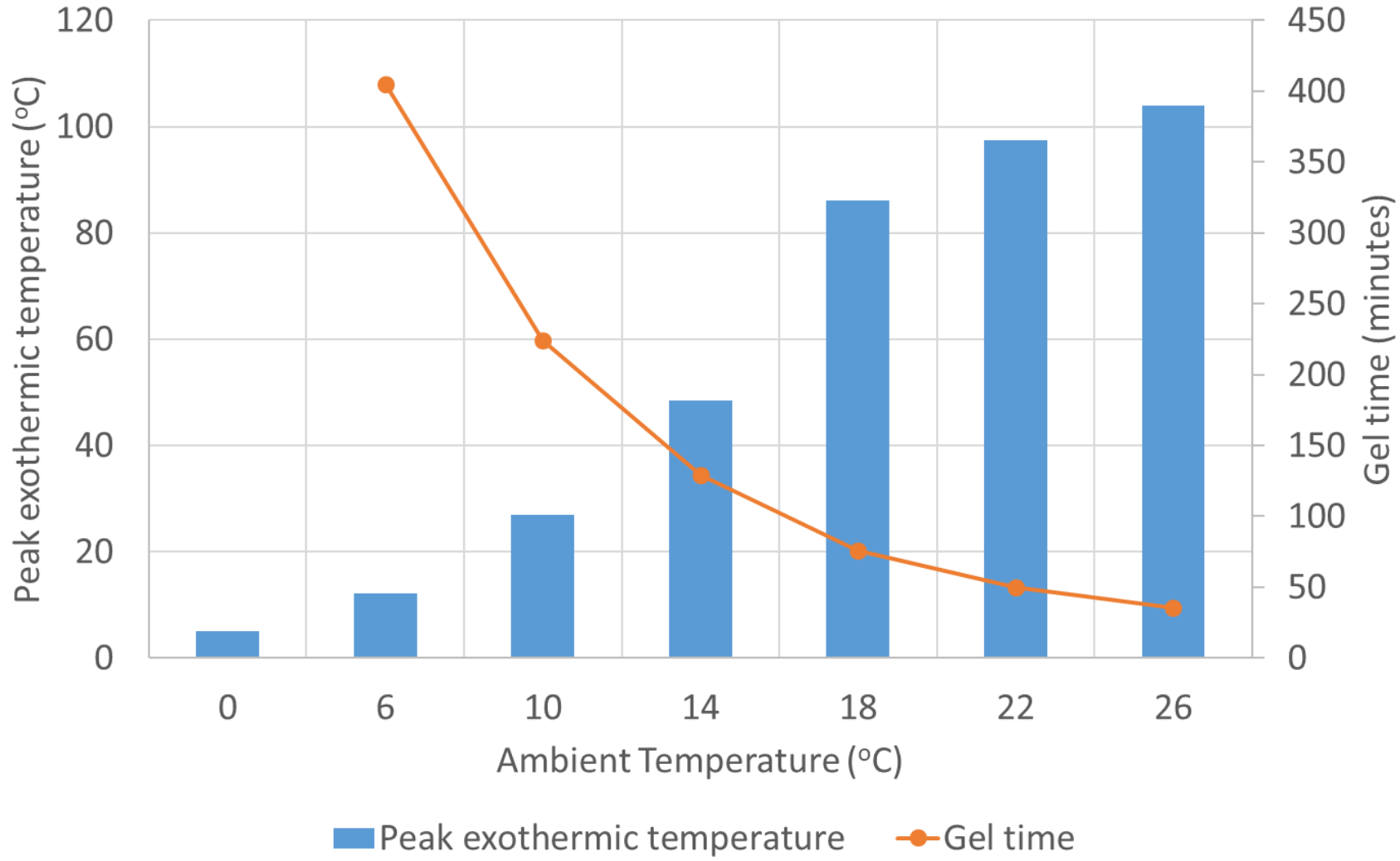


EXPERIMENTAL STUDY

- Key take always from these results:

As

Ambient air temperature

Peak exotherm temperature

Degree of cure

Gel time

INDUSTRIAL CASE STUDY

- Several companies in the Okanagan (BC) reported issues with inconsistent product quality depending on the season in which they were manufactured
  - More warranty claims from products built in the winter vs. summer
  - …parts shipped to across the Pacific Ocean in a shipping container… arrived in a different shape…

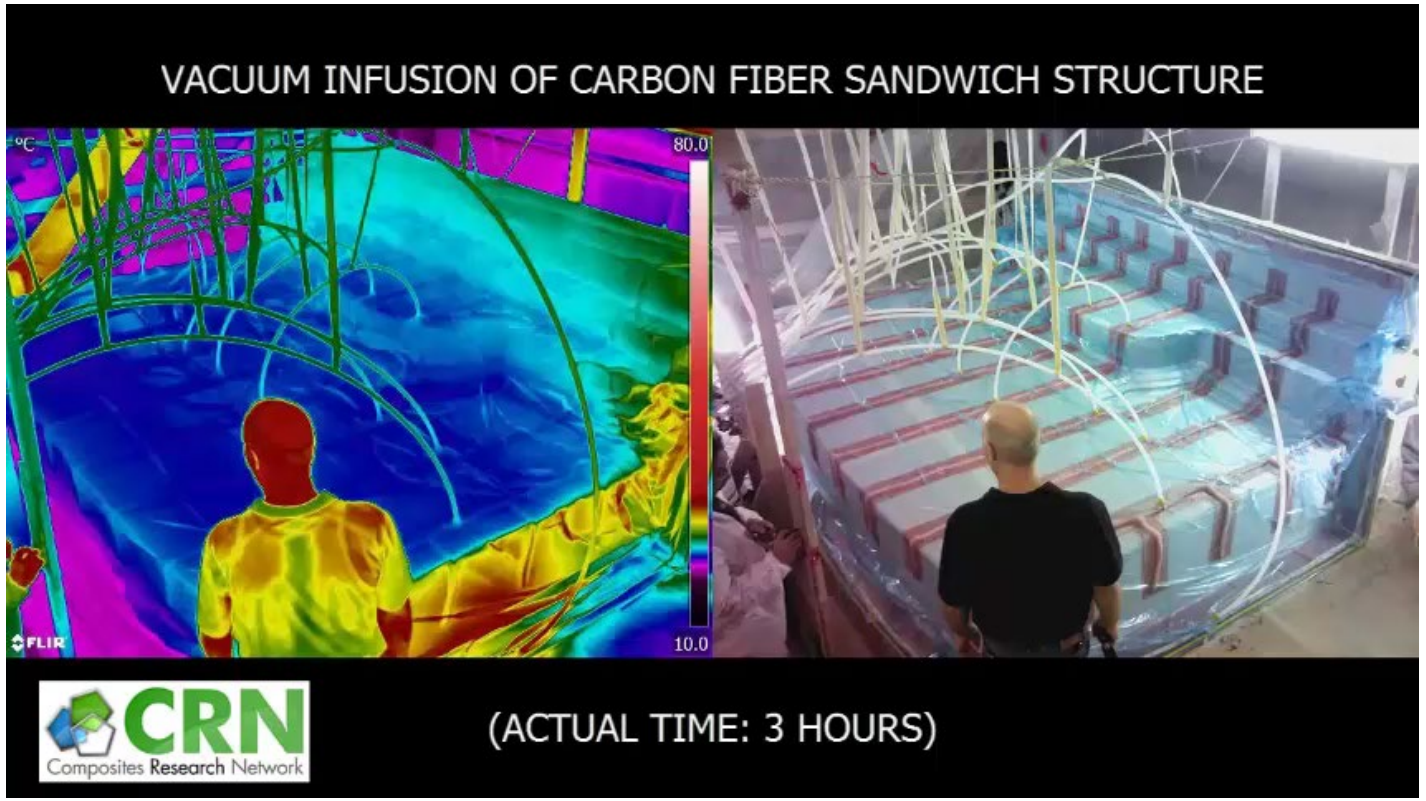
- Glass fibre-polyester used - sourced from same manufacturer in each case
- Parts were cured at *ambient* air temp

MANAGING THE CURE

- *What can we do to address this?*
- Not practical to use a convection oven for large parts
- In-mould temperature control can be expensive, challenging with composite tooling
- Strategies
  - Forced air (heater)
  - Infrared heater
  - Tent around the part and heat with heater
    - Careful with this, could result in uneven temperature distribution
  - Insulation/blanket
    - Heat is being generated, just a matter of keeping it in
  - Heated blanket

MANAGING THE CURE

- Infusion of stairs/deck for 145’ luxury yacht



Thank you for joining us!

Keep an eye out for announcements on the next AIM events
And don't forget to visit the KPC for more information:

https://compositeskn.org/KPC

Questions?

For more information on future dates and times visit:

compositeskn.org